COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

January 1954

UNIVERSITY
OF MICHIGAN
FEB 3 1954

Highgrove Steam Plant of California Electric Power Company

The Controlled-Circulation Boiler

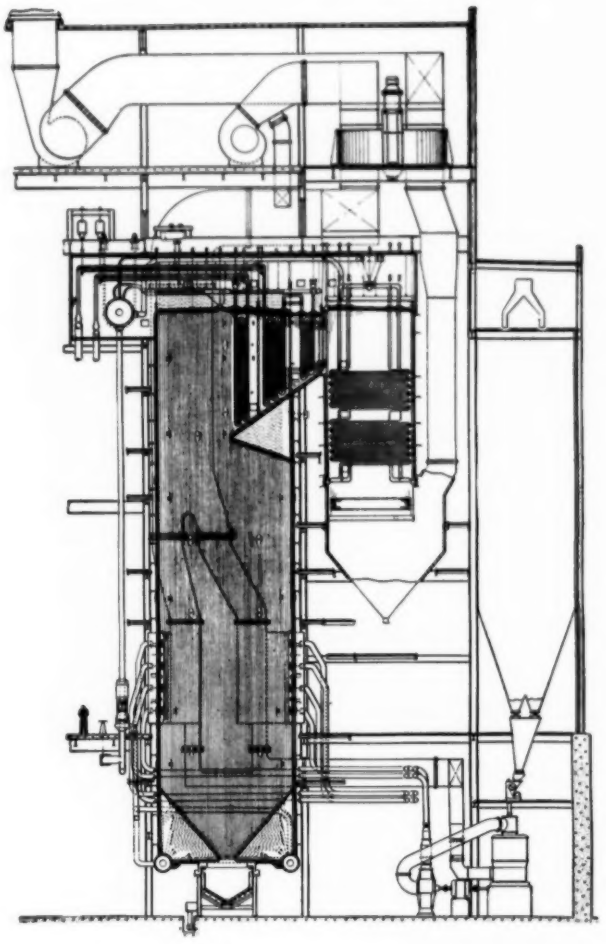
Power Practices in 1953

Manpower and Other Operating Costs

RIVERBEND STEAM STATION

Duke Power Company

C-E controlled circulation boilers



The C-E Unit shown above is one of two duplicates now in process of fabrication for the Riverbend Steam Station, Mt. Holly, N. C., of the Duke Power Company.

Each of these units is designed to serve a 135,000 kw turbine-generator operating at a throttle pressure of 1800 psi with a primary steam temperature of 1000 F, reheated to 1000 F.

These units are of the controlled-circulation, radiant type with a reheater section located between the primary and secondary superheater surfaces. An economizer section follows the rear superheater section and regenerative type air heaters follow the economizer surface.

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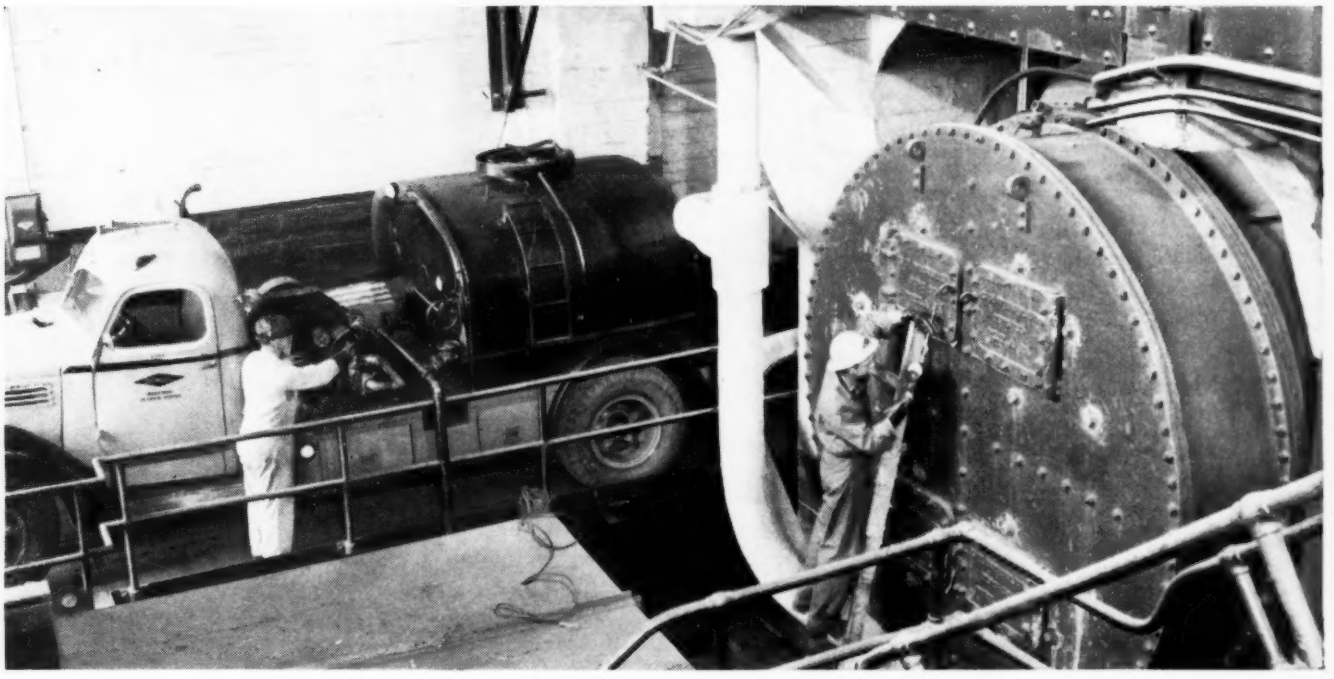
Fly ash, soot and carbonate deposits removed from condenser by Dowell; vacuum increased



Fly ash and carbonate deposits on the water side of an 800-KW turbo surface condenser had reduced vacuum from a normal 28″ to 24″. The temperature of the water leaving the condenser had dropped from 95°F. to 85°F.

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Editorials

Green Light for Nuclear Power?

President Eisenhower's December speech before the general assembly of the United Nations expressed most forcibly the desire here in the United States to see the world in general get about the business of developing an atomic energy program that will be a benefit to all mankind. Much of the U. S. thinking on harnessing atomic power has been rather openly discussed in the technical press, before various engineering societies and at numerous industrial conferences. It will be extremely interesting to see whether, in the light of President Eisenhower's speech, our government is willing to revise the McMahon Act to expedite nuclear power development within our own country.

There are, of course, some notable examples of governmental and private industry cooperation, especially in reactor power technology.

At the moment we know nuclear power is not commercially feasible in the U. S. A. The reasons behind this appraisal make good sense. In a fuel-rich country such as ours atomic materials as possible power generation sources must take their place in competition with other fuels. This philosophy of open competition has equipped our power plants to fire an ever wider range of fuels at lower station heat rates and at attractive costs even against a definitely inflationary background. It seems logical, then, that those most deeply involved in power generation, the public utility industry, will continue to explore further economies and newer designs along the conventional lines that promise immediate returns. Under the McMahon Act nuclear power does not fit into this picture.

We believe the federal government could further the Eisenhower aim by devising ways and means to obtain greater public utility and private business participation in atomic energy studies. At a recent National Industrial Conference Board meeting on Atomic Energy in Industry, E. H. Dixon, president, Middle South Utilities, Inc., pointed out one such way through a revision of the McMahon Act. The revision entailed (1) licensing electric power companies and others to proceed with nuclear power development; (2) arranging for ownership and disposal of fissonable materials, and the means for producing them. Further, patent protection would greatly enhance incentive and accelerate research and development.

To our way of thinking atomic power will experience its most far-reaching as well as its most rapid growth under just such a competitive climate. Let's hope that the Atomic Energy Commission will apply the Eisenhower thinking to our own domestic situation.

Professional Development

One of the perennial topics of conversation among engineers concerns the manner in which young engineers mature as they gain industrial experience. But now the talking stage has been augmented by tangible action. Two recent reports tell of activities designed to stimulate professional development and provide evidence of typical attitudes of engineering graduates of the past several years.

The 21st Annual Report of the Engineers' Council for Professional Development includes an account of the extensive project undertaken this past year in Cincinnati. Under the direction of a full time leader, Professor Cornelius Wandmacher, the program has placed major emphasis on the pattern of community organization and continued educational opportunities. Next year it is expected that more attention will be given to a study of orientation and training programs in industry. Considerable support for the Cincinnati experiment has been received from local industrial organizations and from local sections of the national engineering societies as well as the Engineering Society of Cincinnati. On the basis of experience gained in stimulating professional development in Cincinnati it is planned to undertake similar projects in other communities.

In another area there is evidence of the possible danger in looking at professional development in too idealistic a manner. Attitudes of the young engineer must also be considered. Keynoting a report prepared by the Professional Engineers Conference Board for Industry with the cooperation of the National Society of Professional Engineers is the thought that security is the primary objective of the young engineer. This is the conclusion reached from a survey of more than 1300 engineers and published in a report entitled "How to Attract and Hold Engineering Talent." The reason attributed for the emphasis on security is that the young graduate is quite depression conscious even though he may have been but a small child during the 1930's.

The Cincinnati experiment of the ECPD is an attempt to coordinate activites that have hitherto been left to chance. It is to be hoped that the desire for security, if the attitude is as widespread as the survey indicates, will not be so strong as to impede constructive experiments to stimulate professional development.

The Controlled-Circulation Boiler

By W. H. ARMACOST

Vice-President in Charge of Engineering, Combustion Engineering, Inc.

Many of the factors which made possible the development of controlled-circulation boilers are discussed in these excerpts from a paper presented at the 1953 ASME Annual Meeting. In addition to descriptions of a number of installations, information is presented on operation and performance of units at Chesterfield and Kearny Stations.

IN the early days boiler designers had ample tolerance in setting up circulation rates. This was due to the large difference between the density of water and steam at relatively low pressures. In fact, in many cases, it was necessary to retard the circulation rate to reduce turbulence in the drums. As pressures and heat inputs increased, more and more design attention was required and it was necessary to elevate the furnace-boiler system to obtain the necessary circulating head. One approach to this problem has been the development of controlled-circulation boilers.

Actually, there are only a few fundamental differences between controlled- and natural-circulation boilers. A typical design of controlled-circulation boiler, as shown in Fig. 1, will make this clear. It will be noted that a steam-water drum is employed and a mixture of steam and water from the steam-generating tubes and feedwater

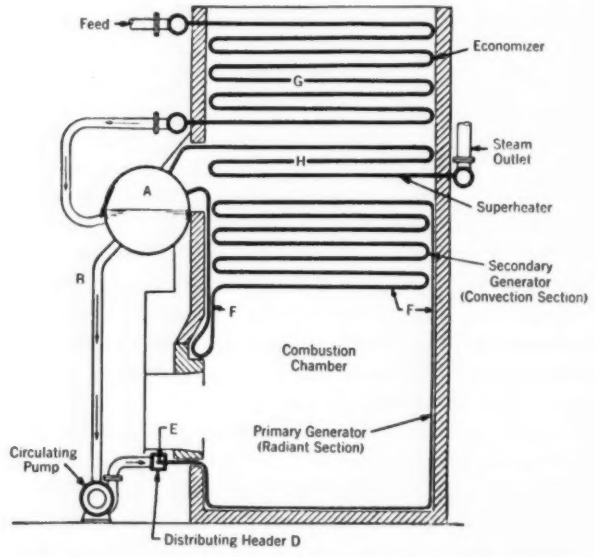


Fig. 1—Schematic arrangement of controlled-circulation boiler

from the economizer enters the drum. Small downtake tubes or large pipes carry the excess boiler water, after it has mixed with the feedwater, back to the entrance of the steam-generating circuits, and outlet tubes from the boiler drum deliver the separated steam to the superheater. All of these operations are quite similar to the conventional natural-circulation boiler, the chief differences being that pumps are used to "force" the circulation of water through the evaporative section of the boiler and orifices are used to "control" its distribution. More specifically, by controlled circulation is meant those features which permit the designer to proportion the water supply to a furnace wall, or boiler section, or to individual tubes in accordance with predetermined requirements, or to change the total flow or the distribution within limits at any subsequent time. This is accomplished by orifices in the inlet parts of the steam-generating circuits.

The controlled-circulation units employed in this country have been of two types. The first, Fig. 2, used in the early boilers consists of one drum, water walls, superheater, reheater and economizer as in any conventional boiler, but the water is distributed from the downtakes to a suction manifold through the pumps to a ring header, which supplies the entire water wall through individual water-wall headers. In the ring headers are four master strainers. Distribution of the "strained water" to the water walls is controlled by orifice plates inside of the headers, each two orifice plates being protected by a strainer. In addition to the regular water-wall circuit, there is a second circuit, referred to as a panel wall, which cools the area in the vicinity of the reheater. The panel wall is supplied water directly from the discharge header and has separate strainers. The steam-and-water mixture flows into the single drum where the steam is separated by means of turboseparators and from thence to the first or low-temperature section of the superheater.

The second type of controlled-circulation unit and that used in the later installations, Fig. 3, is somewhat simpler than the first in that no headers or master strainers are employed. Instead, one or two distribution drums are used at the bottom of the unit. These are fed from the pump-discharge manifold and supply the water walls through orifice plates inside the drums. This makes for easier maintenance and general overall simplicity.

One of the features of controlled circulation is that small tubes are used. These range from 1 in. to $1^5/_8$ in. OD. However, the controlled-circulation principle could be applied to a boiler with large tubes but a great amount of water would have to be circulated to obtain satisfactory water velocities. To cut down on the amount of water circulated and for reasons pointed out later, the small tubes are used.

Early Installations

The first high-pressure boiler in the United States utilizing controlled circulation was installed at the generating plant of Montaup Electric Company at Somerset, Mass. The Montaup boiler was completed in 1942. It was designed for 2000-psig drum pressure and a steam temperature of 960 F at the superheater outlet. It supplied 650,000 lb of steam per hr to a 25,000-kw topping

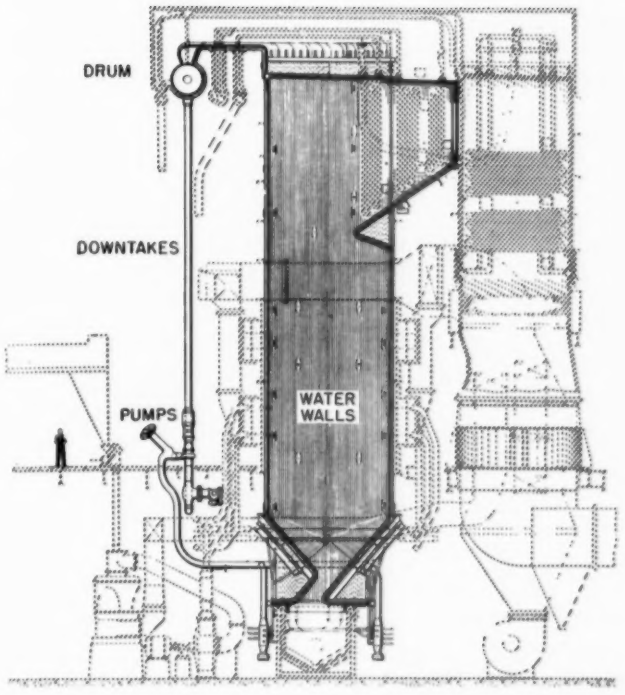


Fig. 2—Arrangement of controlled circulation at Chesterfield Station, Virginia Electric & Power Company

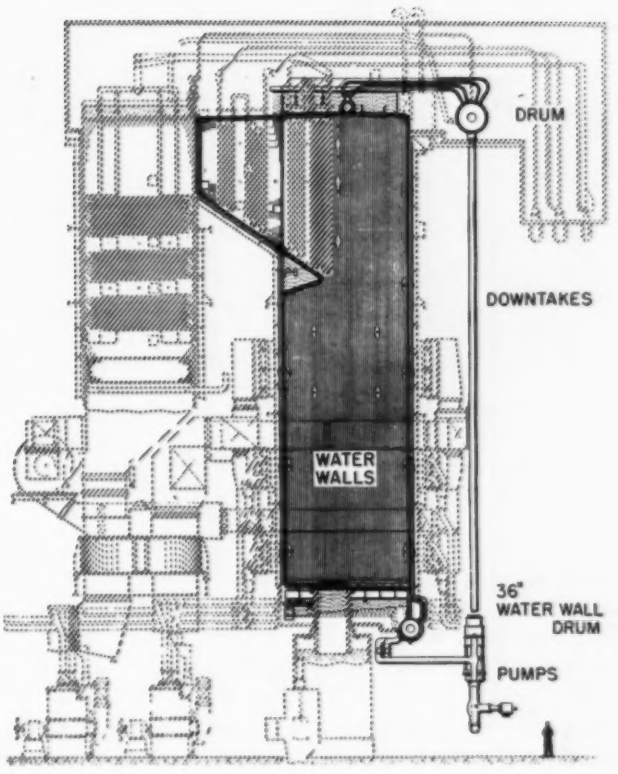


Fig. 3—Arrangement of controlled circulation at Kearny Station, Public Service Electric and Gas Company

turbine, the exhaust being reheated to 750 F. This was the first large boiler in which the furnace comprised all of the evaporative surface. The reasons for adopting controlled circulation at Montaup may be summarized by stating that the objective was to obtain the greatest possible amount of topping power from a given space in an existing building and within a definite appropriation.

During the early operation of the Montaup boiler unforeseen difficulties developed in boiler-water conditions. Similar difficulties arose with a natural circulation boiler installed about the same time. In both cases, precipitation of salts occurred due to the fact that the solubility of phosphate and sulfate decreases as the temperature rises. In the case of Montaup the difficulty was aggravated by condenser leakage which built up a considerable concentration of soluble salts in the boiler water. Marked improvement resulted from substitution of potassium water-treating chemicals for the sodium ones previously used. In addition to this, the ultimate solution of the problem involved close control of the addition of treating chemicals, lower excess of treating chemicals and maintenance of condenser leakage at a minimum.

Another difficulty at Montaup was with the sealing of the circulating pumps. At no time was there failure of circulation or boiler outage due to pumps, but the gland had to be redesigned and rebuilt to hold down leakage.

A feature in the construction of the Montaup boiler was the use of welded connections for connecting tubes to strength-welded nozzles on the headers and drums. A typical arrangement of the reinforced nozzles is shown in Fig. 4. This arrangement eliminates rolled or mechanical joints and therefore danger of leaks. This is of extreme importance in the case of high-pressure boilers and the practice is being followed in present-day controlled-circulation units; also, where it is applicable, in natural-circulation units.

During the intervening years the early difficulties have been overcome; for the past several years the availability of this unit has equaled or exceeded the average reported for boilers of comparable size and operating conditions. Needless to say, the experiences gained have been invaluable in the design and development of present-day controlled-circulation boilers.

Later Installations

The first postwar controlled-circulation reheat unit to go into operation was at the Chesterfield Station of the Virginia Electric and Power Company. Its capacity is 750,000 lb per hr at 1500 psig with 1000 F primary steam temperature and 1000 F reheat temperature. Water walls comprise the entire evaporation surface. Water from the drum passes through downcomers to the circulating pumps and thence to headers where it is distributed to the tubes. This boiler employs the same distribution-header arrangement as in Montaup, but an improved orifice arrangement was installed. Orifice plugs were not used for each tube; rather an orifice holder and screen were installed for each two or three tubes through a seal-welded handhole. This development greatly simplified the installation and maintenance of the units.

Another development in the case of the Chesterfield boiler concerned the circulating pumps. Deriving from experience at Montaup, pumps of the injection type were developed so that mechanical seals could be installed at a later date. At the present time satisfactory seals are in use to prevent sealing water entering the boiler. Seals are being developed to prevent leakage to atmosphere. Still another development involved the drum internals. Based on the experience of Montaup, a

Fig. 4—Kearny drum showing welded reinforced nozzles

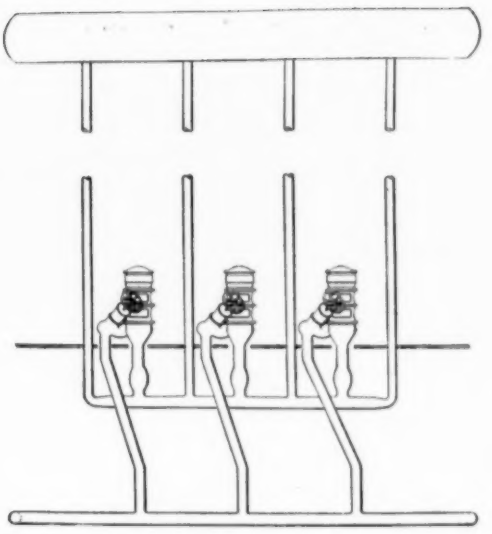


Fig. 5—Arrangement of circulating pumps and piping of controlled-circulation boilers

"centrifugal type" separator was devised. The equipment was previously found to be so efficient that no dry drum was included in the Chesterfield boiler. Operating experiences at Chesterfield have indicated satisfactory steam purity.

The unit recently put into operation at the Kearny Station of the Public Service Electric & Gas Company is typical of current installations of controlled-circulation boilers. This unit has a continuous capacity of 955,000 lb of steam per hr at 2650 psig. The primary steam temperature is 1100 F and the reheat temperature 1050 F.

In addition to further developments on steam purification and circulating pumps, this unit has several novel advancements. In the first place the boiler-water circulating or distribution system was greatly improved and simplified. Instead of using headers and strainers, distribution drums are installed at the bottom of the unit, as shown in Figs. 2 and 3. These are fed from the pump-discharge manifold and supply the water walls through screens and orifice plates inside the drums. Such a system is much simpler from a maintenance standpoint.

Also considerable improvement has been made in downtake piping and valves. In the case of Montaup the circulating pumps were installed on the floor below the unit. The supply pipes to the pumps were connected to a common header which received its water supply through two pipes connected to the bottom of the boiler drum. Provision for expansion was obtained by a system of pipe bends at the rear of the units. Discharge lines from all three pumps were connected to a common header. Expansion in the latter case was absorbed in the loops of tubing used to connect the discharge header to the main distributing header at the bottom of the unit. An objection to this scheme is the necessity of providing for expansion in large-diameter heavy-wall pipes without causing high stresses in the pipe connection to the pump casing.

An improved arrangement of pump supporting, downtake piping, pumps and valves, and that used in current installations, is shown in Fig. 5. Water is supplied to the common downtake header through four pipes connected to the bottom of the drum. The three pumps are mounted on the downtake header through the pump intake located at the bottom. Discharge lines from all three pumps connect to a common discharge header which, in turn, connects with the main distributing headers of the water walls. In this manner piping and expansion loops are avoided since the pumps are not attached to the building structure.

Each pump is equipped with a motor-operated inlet valve with screwed down-stop check on the outlet. Normally two pumps are in operation and a third is for standby. Provisions are made for maintaining all piping and the idle pump hot by one inch recirculating lines, through which hot water is recirculated continuously by utilizing the differential head across the pumps. This eliminates stresses due to expansion.

Another feature of this boiler is the panel-wall construction. Panels are possible due to uniform metal temperatures obtained with controlled circulation. Such a typical arrangement is shown in Fig. 6. Use of small tubes, $1^1/_4$ in. to $1^1/_2$ in. OD, greatly facilitates the wall construction. That is, these tubes may readily be made into panels and are easy to form into definite shapes, for example around doors, inspection holes, and so on.

Turbo-Steam Separator Development

In the case of the Montaup boiler, it was desired to have steam of maximum purity. Consequently, the design called for a dry drum. When it was found that the steam purity was dependent on water level, replacement internals were installed. These gave a purity well within the guarantee. However, it was realized that still greater steam purity could be obtained by taking advantage of the relatively great pressure drop available on controlled-circulation boilers. After considerable development work, a greatly improved system resulted.

The steam-drum internals finally adopted and used on current controlled-circulation boilers consist of a steam-water mixture collecting compartment formed by internal baffles, with turbo-steam separators uniformly spaced and mounted on the collecting box or compartment. A symmetrical arrangement can be employed so that there are two rows of the turbo-separators with a common internal baffle and a collecting box on either side of the drum. A typical arrangement is shown in Fig. 7. The operation of the steam-purifying equipment is as follows:

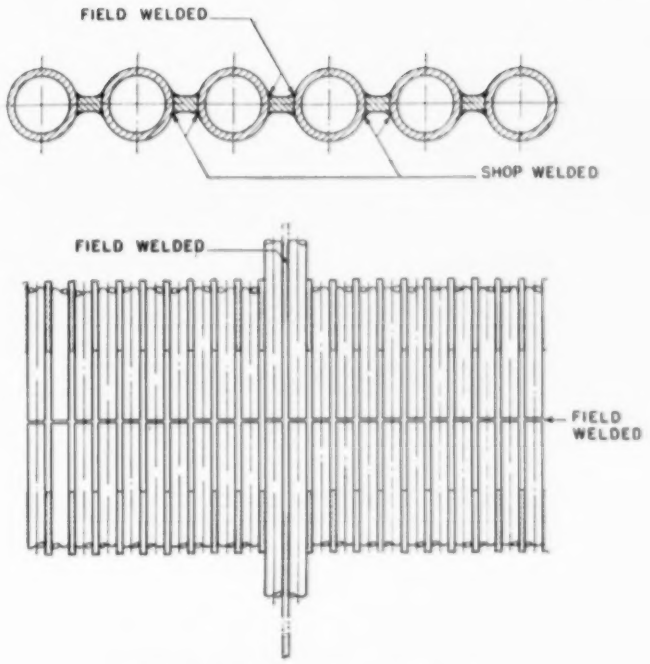


Fig. 6—Welded water-wall panels

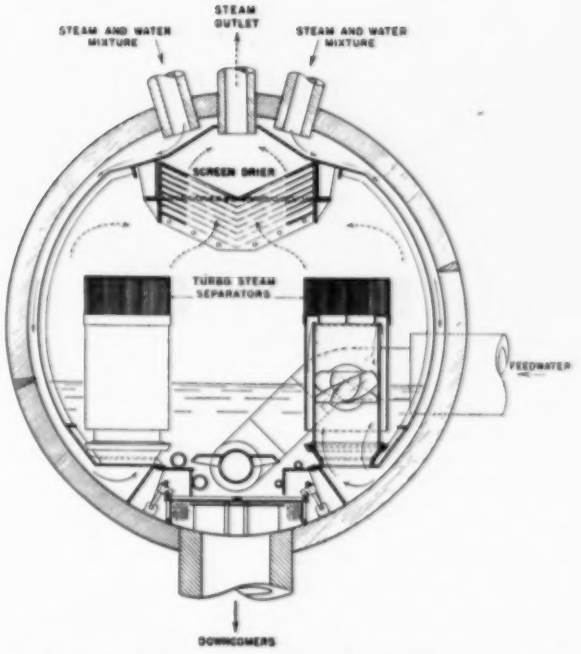


Fig. 7—Section of drum showing cyclone separator and drum internals

Steam-water mixture enters the top of the drum through nozzles discharging into an annular space formed by internal baffles. Flow of the mixture is directed downward behind symmetrical baffles around the entire drum surface maintaining a uniform drum-wall temperature, and then into the turbo-separators. The latter contain a center core and vanes which gives the mixture a spinning or centrifugal motion thereby throwing the water to the outer edge of the inner tube. Directly above the directional vanes and cores there is a skim-off lip which directs the water over the top of the inner tube and thence through the annular space to the drum. This is the primary separation stage. The relatively dry steam then passes through two opposed banks of closely spaced corrugated plates, which changes the direction of the steam many times and throws out much of the remaining water. This is the secondary separation stage. The third and final stage of purification is accomplished in the screen dryer.

Steam-drum internals of this type were first used in controlled-circulation boilers built for the U. S. Navy Bureau of Ships. The units were thoroughly checked at the Naval Boiler and Turbine Laboratory at the Philadelphia Navy Shipyard. Excellent results were obtained.

In 1950, in order to test internals of this design in a large high-pressure boiler, a similar set of internals was installed in the controlled-circulation boiler at Montaup. Tests results showed less than 0.5 ppm of solids in the steam when 960-ppm solids were present in the boiler water. Also, it was found that variation of water level had little if any effect on the steam purity. Furthermore, it was found that the dry drum was not required; therefore this is eliminated in current designs. Test results on recently installed controlled-circulation boilers show a solids content in the steam of less than 0.25 ppm.

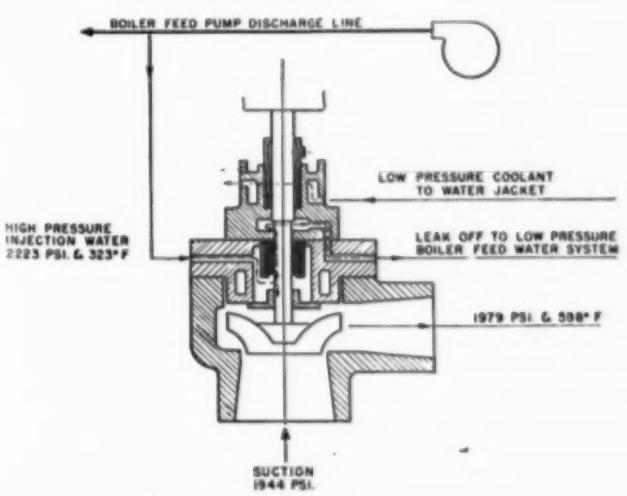

BOILER FEED PUMP DISCHARGE LINE
LOW PRESSURE COOLANT TO WATER JACKET
HIGH PRESSURE INJECTION WATER 2223 PSI. & 323° F
LEAK OFF TO LOW PRESSURE BOILER FEED WATER SYSTEM
1979 PSI. & 598° F
SUCTION 1944 PSI.

Fig. 8—Schematic arrangement of circulating-pump seal

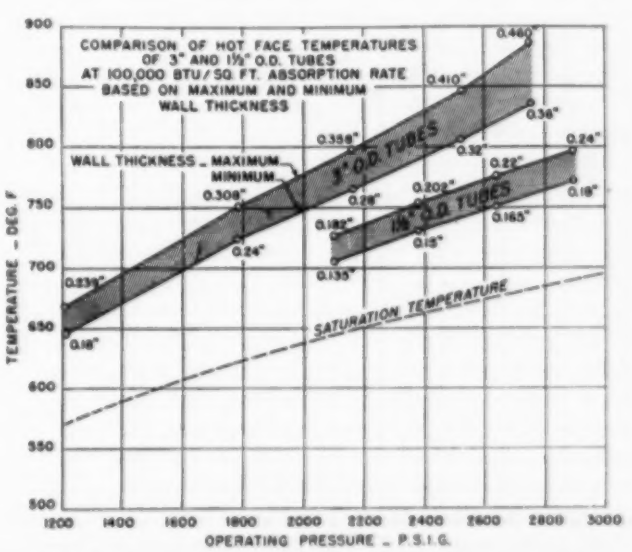


Fig. 9—Comparison of tube hot-face temperatures

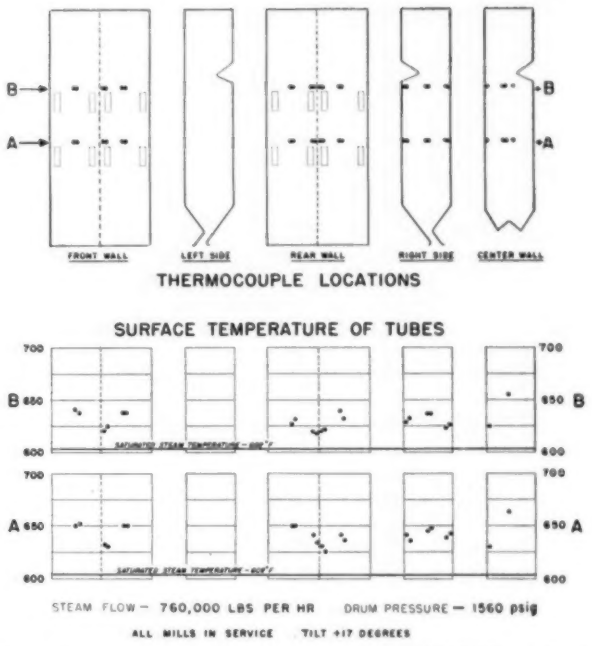


Fig. 10—Tube temperatures in Chesterfield Unit No. 3

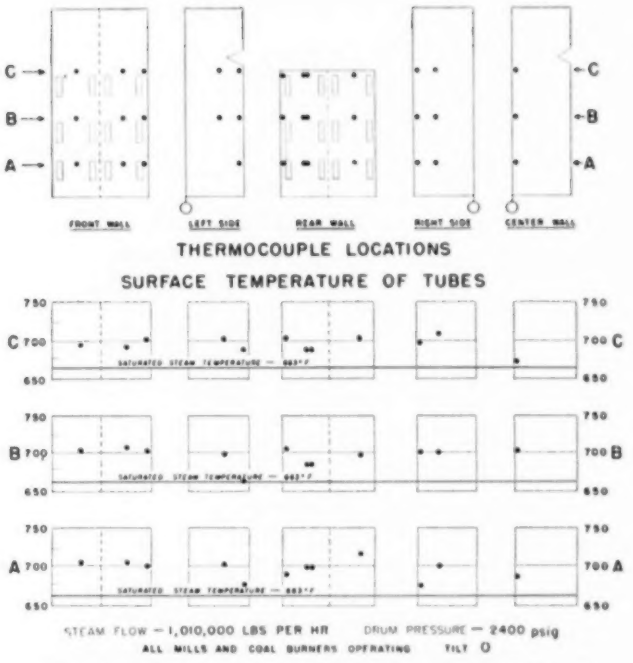


Fig. 11—Tube temperatures in Kearny Unit No. 7

These data are backed by the fact that there has been no loss of capacity of turbines supplied with steam from these units.

A secondary advantage of the turbo-steam separator unit is that no washing operation is involved. Consequently, less steam condenses in the drum with the result that less water has to be circulated. Therefore, a smaller drum can be used and the piping and pump for circulating the water may be smaller. This results in considerable saving in weight, especially since no dry drum is required.

Circulating Pumps

One of the major developments, in fact the one that made controlled circulation possible, concerned the circulating pumps. Generally three pumps are used, two being for service and the third for stand-by. The general arrangement of the pumps is shown in Fig. 8.

The pumps raise the pressure of the water from the drum about 40 psi. This is sufficient to overcome the resistance of the orifice and the circuit proper. Distribution of the water is controlled by selection of the orifice size in accordance with calculated or desired requirements.

Several general types of pumps have been used. In no case has there been any real problem in preventing injection water from entering the boiler. This has been accomplished by using a low differential-pressure mechanical seal. As mentioned, some trouble has been experienced in developing a satisfactory mechanical seal between boiler pressure and atmospheric pressure.

In one type of pump a packing gland is supplemented by a water labyrinth which reduces the pressure stepwise until an ordinary packing gland can be used. Another type uses two impellers, one to circulate the boiler water and the other to circulate cooling water in a closed circuit so as to maintain a uniform temperature for the mechanical seal. It is possible to switch to injection sealing in case of mechanical seal failure.

At present pumps are available having satisfactory seals to prevent injection water entering the boiler through the pump. A development program is under way to obtain a seal of the mechanical type that will satisfactorily seal against the drop from boiler pressure to atmospheric. The current pumps, which are of the injection type, are designed so that mechanical seals can be installed.

Except for starting the circulating pumps, the procedure for putting a boiler in operation is the same as for a natural-circulation boiler. The advantage of having the water circulating during the starting-up period is obvious; that is, temperatures are maintained even throughout the unit which permits rapid starting. The same applies to shutting down the unit, at which time the pumps continue to operate and thus maintain even temperatures. Steaming of the economizer may be prevented by providing a connection between the circulating pump and the economizer-inlet header.

Owing to the importance of water circulation at all times, definite steps have been taken to protect the system in case of failure of a pump. An interlock-manometer arrangement is connected across the suction and discharge headers of the pumps. The manometer has a magnetic float which rises and falls with the differential pressure across the headers. Attached to the manometer are permanent-magnet-activated mercury switches, which are drawn in as the float rises. There are three of these switches, which are set at low, medium and high differential; for example, 8 psi, 20 psi and 40 psi. These switches activate lights on the control board. When all three are lighted there is over 40 psi differential between the headers. This indicates that there are three pumps in service. When two lights are lighted there is about 20 psi differential, which is that developed by two pumps. When only one light is visible there is about 8 psi differential, meaning that only one pump is running; and an alarm is sounded so that load will be reduced manually to approximately 60 per cent. Ac-

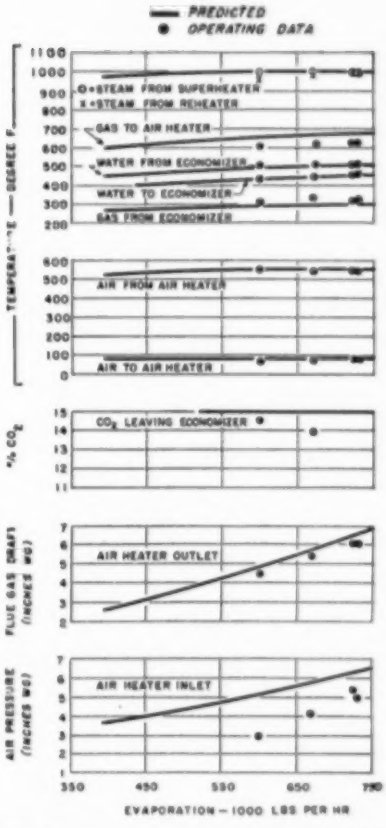


Fig. 12—Performance results, Chesterfield Unit No. 3

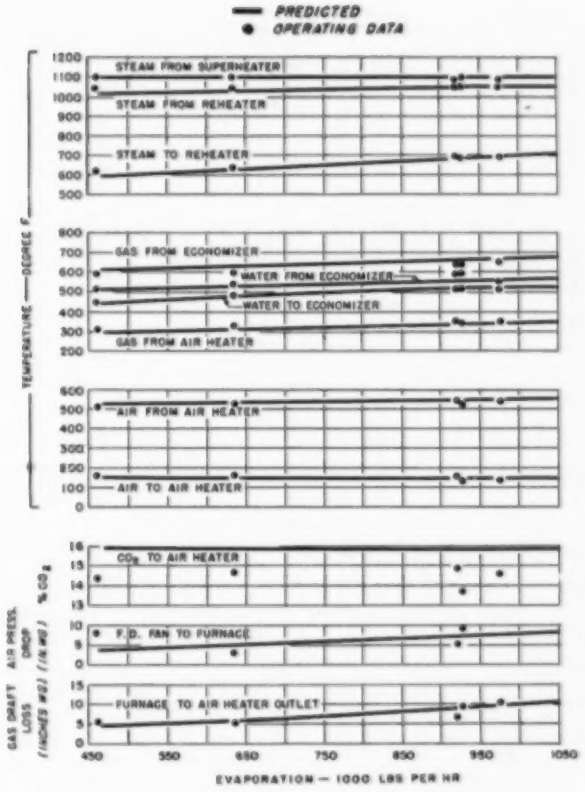


Fig. 13—Performance results, Kearny Unit No. 7

tually, the one pump will circulate sufficient water at normal loads to prevent damage to the boiler for a short period of time. When no lights are on, no pumps are running and all fuel is cut off to the unit by automatic firing relay. Owing to the reliability of the current pumps and the use of the warning-alarm system, there is no longer any apprehension about the circulating features.

Use of Small-Diameter Tubes

Because of the positive and controlled circulation of water in controlled-circulation boilers, and since relatively low circulation ratios of the order of 4 or 5 to 1 are used for high pressure, it is possible to use small tubes; that is of the order of $1^1/_4$ in. to $1^1/_2$ in. OD. Many advantages arise from the smaller tubes. The weight and thickness of the tube are greatly reduced. As would be expected, the velocity is much greater through the tube. Since a thin tube is used the temperature of the tube wall is low and as a result thermal and, therefore, total stress in the tubes is less. This results in a greater overall "real" safety factor. This is illustrated in Table 1 which compares $1^1/_4$-in. and 3-in. tubes for 2650 psi.

Referring more specifically to high-pressure conditions, as pressures are increased tube-wall thickness increases and as a result of the thicker tube metal, there is a greater temperature difference or drop through the metal. This together with the fact that saturation temperature increases with pressure, means that the tube skin temperature may become excessive and lead to danger of failure.

The temperature drop through the wall for a given tube thickness, of course, will depend on the heat-absorption rate. Temperature drops of more than 100 deg F may well exist. The higher metal temperature reduces the strength of the metal and requires an increase in thickness of the tube. This increases the temperature drop and a "vicious cycle" results.

The thermal stresses so developed may become appreciable as compared to the stress resulting from pressure inside the tube. Therefore if a design is based on the ASME Boiler Code, which is based on pressure stress only, the desired factor of safety may not result; that is, the combined pressure and temperature stress may greatly exceed that for pressure alone. Table 1 illustrates this fact and again the advantage of a smaller tube is obvious. Also it should be borne in mind that the Code tube metal thickness is the minimum requirement. Manufacturing tolerances on hot finished tubes may be as much as 33 per cent over this minimum. Thus, in the thicker sections of the tube, the temperature drop is greater and consequently the tube skin temperatures are higher with the probability of higher thermal stresses being developed.

Some idea of the importance of this fact is shown in Fig. 9, where the upper curve shows tube skin temperatures for maximum wall thickness and the lower curve those for minimum wall thickness. Note that for an operating pressure of 2650 psig, using the minimum-thickness curve, the tube skin temperature for a 3-in. tube is 820 F, whereas that for a $1^1/_2$-in. tube is only 752 F. Using the maximum-thickness curve the value for a 3-in. tube is 868 F whereas for a $1^1/_4$-in. tube it is only 777 F. Again the advantage of a smaller tube is evident.

Referring once more to tube diameters, the data in Table 1 (following page) on tube and water weight emphasize the advantage of small tubes. Note that in the

case of a wall composed of 1½-in. tubes, the tube weight is only 49 per cent as much as in the case of 3-in. tubes. The weight of water in the 1½-in. tubes is only 51 per cent as much as that in the 3-in. tubes. The weight saved means less load on the foundations and reduced size and weight of structural supports. Owing to the smaller tubes much less weld metal need be deposited in erection. A further advantage of the lower weight of the tube metal and water is that in starting-up considerably less fuel is used and the boiler can be put on the line quicker. For the same reason it can be shut down more quickly.

TABLE 1—COMPARISON DATA FOR 1½-IN. AND 3-IN. BOILER TUBES AT 2650 PSIG

Tube Diameter	3 In.	1½ In.
Wall thickness	0.34	0.165
Velocity ratio	1	1.96
Tube weight ratio	1	0.49
Water weight	1	0.51
Wall thickness, min and max	0.34 and 0.435	0.165 and 0.219
Heat absorption, Btu/sq ft/hr	100,000	100,000
Temperature gradient wall, deg F	126	63
Temperature gradient film, deg F	10	10
Saturation temperature, deg F	679	679
Hot-face tube temperature	815	752

Still other advantages of small tubes are that they can be bent more easily to fit around burners, doors, soot blowers and so on. They also are more readily butt-welded in the field because, even though there are more tubes to weld, the amount of weld metal required is much less.

Finally, a furnace wall made of small-diameter tubes presents a more nearly plane surface than one with larger tubes. This is advantageous from the standpoint of slag removal, as well as for the arrangement of wall backing and insulation.

A possible disadvantage of the small tubes is lack of structural strength in the wall. This, however, is readily offset by the use of girth members at closer intervals.

Welded Walls

A feature of the Kearny and some of the later boilers is the welded panel-wall construction. The Kearny boiler is designed for pressurized operation although induced-draft fans are provided in case suction operation is required. Owing to the even temperature in the walls resulting from controlled circulation, this welded design was made possible; it was facilitated somewhat by the small tubes used. These tubes were shopwelded into panels. Employment of the panel construction eliminates the use of a steel casing for pressurized furnaces or making a gas-tight setting on suction firing.

Operating Data and Performance

Fig. 10 shows the profile of the furnace walls on the Chesterfield boiler and just below this profile is shown the maximum temperatures recorded in reference to saturated temperatures occurring due to pressure carried in the tubes.

Fig. 11 shows the profile of the furnace walls on the Kearny boiler and the resulting temperatures which are higher due to the higher saturated temperature resulting from the greater pressure within the tubes.

In addition to the thermocouples, calibrated pitot tubes with manometers were installed in representative circuits to check the actual flows against those expected. The flows were measured in a similar manner in the four downcomer pipes as this gave a check on the circulating performance. All performance measurements obtained came within the prescribed limits for these boilers.

It is interesting to compare expected performance with actual results. Therefore, In Fig. 12, the solid lines show the expected performance, whereas the dots show the actual results obtained at Chesterfield.

Fig. 13 shows the expected in relation to actual results obtained on the Kearny boiler.

High Temperature Effects on Chrome Steel

The entire field of metals and heat transfer materials has been a continuing object of intensive study for years. Recent advances in power plant operating pressures and temperatures along with the intensified research into nuclear power have furthered these investigations. Some of the investigations make up the subject matter of several papers at the recent ASME Annual Meeting.

"Some 12% Cr Alloys for 1000 to 1200 F Operation," by **D. L. Newhouse, B. R. Sequin** and **E. M. Lape,** metallurgical engineers, General Electric Co., presented a compilation of representative data from the various laboratories of GE on various of the 12 per cent Cr steel modifications. The ones presented have been produced and used in commercial quantities for such service as turbine bolting, compressor blading, steam turbine buckets.

One interesting note was the fact that the reported 12 per cent Cr grades had, at 1000 F, almost as great a deviation in thermal expansion below low alloy steel as did the 18–8 steels above that of low-alloy steels. Translated to other terms this means that heating a 12 per cent Cr alloy bolt to 1000 F in a low-alloy flange sets up higher stresses at operating temperature for a given tightening practice than if bolt or flange had the same expansion characteristics. Similarly an austenitic bolt in a low alloy flange would loosen by 0.002 in. per in. of length on heating to 1000 F. As a result good practice calls for tightening 12 per cent Cr to a lower initial stress value at room temperature when bolting low alloy flames.

Other test data indicated the tensile modulus of elasticity is some 30 to 35 per cent lower at 1000 to 1050 F than at room temperature. Creep and rupture behavior at high temperature were evaluated by the Larson and Miller method of judging time-temperature relationship. Detailed rupture test data were furnished plus relaxation test information obtained from Robinson step-down flow-rate tests, smooth and notched bar rupture ductility data, tempering effects and stress corrosion. The authors reported satisfactory surface hardening experiences with an ammonia gas method of nitriding and mentioned briefly the proper procedures for good welding.

Power Practices in 1953

POWER developments over the past year feature: (1) the highest 12-month (November 1952–October 1953) electric energy production to date ever recorded by the public utilities—up 10.9 per cent to 437 billion kwhrs, (2) a combined utility and industrial energy production that reached 11.9 per cent above the same period a year ago, to a total of 508 billion kwhrs, (3) a utility and industrial generating capacity that aggregated 104,442,700 kw as of October 31, 1953. All the foregoing are based on the latest available Federal Power Commission reports. This same source further puts installed capacity of utility generating plants at 88,617,609 kw and for industrials, 15,825,091 kw, including the stationary plants of electric railroads and railways.

New Plant Capacity Lags

The calendar year, 1953, should have seen the total power generating capability of the nation's electric power system reach about 93,000,000 kw according to the Edison Electric Institute's Fourteenth Semi-Annual Survey. Of the 11,400,000 kw planned for 1953 installation, though, only about 5,500,000 kw went into service during the first nine months of the year, leaving a slightly larger amount yet to go in during the closing three months.

It is rather doubtful that all the remaining, roughly 6,000,000, kw will have come into service by the year's close. Earlier material shortages, plus construction labor difficulties in some parts of the country, have now been joined by a considerable lessening in the urgency to get this new power capacity on the lines. As a direct result all the 1953 planned capacity growth will not materialize.

Indications of this easing off in power demand can be seen in the revised December 1953 peak load, down about 1 per cent from the E.E.I. April estimate to 82,100,000 kw. Undoubtedly the cessation of the Korean War has contributed to this drop in expected load and removed the pressing urgency of many power building programs. Some of this feeling will certainly influence the E.E.I. announced schedule for 1954 and the immediate years to follow. That schedule calls for bringing 14,000,000 kw of new capacity into service in 1954, followed by 11,000,000 kw more in 1955.

Despite what looks like a definite slowdown in new power plant capacity gross margins for the country as a whole show relatively little change compared with earlier estimates. Reductions in estimated capability are offset by somewhat similar reductions in peak load forecasts. The gross margins, based on median hydro conditions, range from 13.4 per cent in 1953 to 18.7 percent in 1955.

In particular, though, some power systems have vigorously pushed new plant construction. On the next two pages are views of several prominent new power plants that went into service during 1953. The Minnesota Power & Light Co. with its extremely rapid capacity growth of 106 per cent since World War II was topped by the Illinois Power Co. which grew from a 1947 total capacity of 37,000 kw to 519,000 kw. The American Gas & Electric system spent $135,000,000 in 1953 on construction alone. When Muskingum and Kanawha Stations complete their program early in 1954, and their capacity is added to the new Tanners Creek 200,000-kw installation, A G & E will have raised total system capacity 1,000,000 kw within the span of about one year.

Atomic Energy Plants

Over and above the very vigorous power programs of the long established public utility systems there has been the active buildup of large blocs of power in specially formed organizations, the Ohio Valley Electric Co., Electric Energy, Inc., the South Carolina Generating Co., to name the principals, plus the TVA, created to supply the major atomic energy projects.

Ohio Valley Electric Co. brought into being to serve the Portsmouth, Ohio, project reports a schedule for its Kyger Creek Plant for steel work to begin March 1, 1954 and first unit operation a year later. Its subsidiary, the Indiana-Kentucky Electric Corp., begins its steel work on the Clifty Creek Plant January 1, 1954, with first unit operation, scheduled for a year later. Estimated final costs for both plants will reach $320,000,000 exclusive of transmission lines and other externals.

Electric Energy, Inc., together with TVA will supply the government's Paducah, Ky. project. First step in the Electric Energy organization's contribution is the Joppa Station pictured on p. 46 which went on the line this past year.

The Savannah River atomic energy project will draw much of its power needs from a special plant of the South Carolina Generating Co. now going up at Beech Island, S. C.

The TVA's steam plant buildup continues at a strong rate. Orders placed in the middle of the year for the Kingston Steam Plant will make this the world's largest powerhouse when completed. Its nameplate capacity will equal 1,600,000 kw, some 100,000 kw larger than its sister TVA plant, the Shawnee Station, planned for 1,500,000 kw capacity.

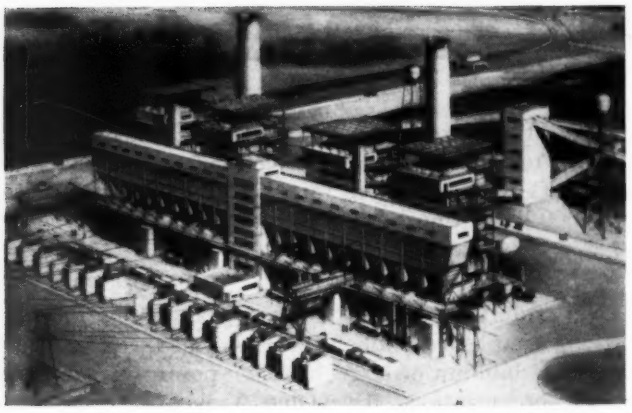
Nuclear Power

The year 1953 has been characterized by some as the Atomic Energy Commission's year of decision. This comment is based on the grounds that a civilian atomic power plant was underway as a result of the October announcement assigning Westinghouse Corp. to the project. Actually, there persists a strong feeling that AEC is still not promoting full industrial participation in areas that would not affect national security. (See Editorial, p. 37.)

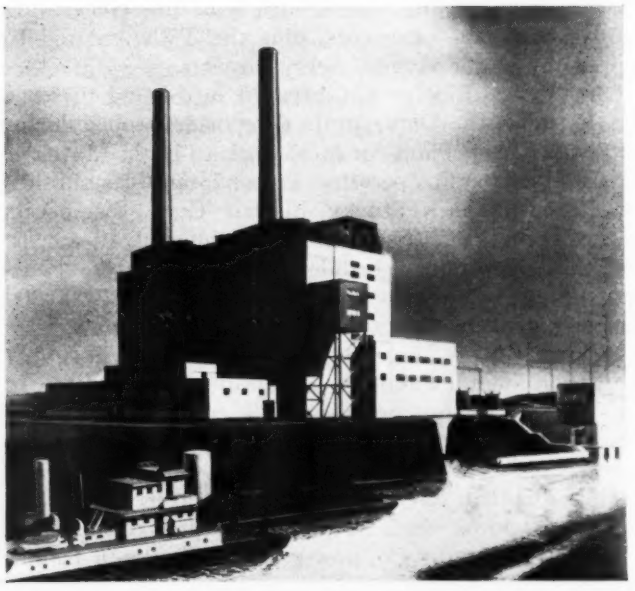
However, a highly important document, "Nuclear Power Reactor Technology", was made available to all interested parties through the Supt. of Documents, U. S. Govt. Printing Office, Washington 25, D. C.; 25 cents. This publication gives the screened reports of the four private industry teams the government formed in 1951 to make, at their own expense, initial surveys of reactor technology.

These teams—Dow Chemical Co. and Detroit Edison Co.; Monsanto Chemical Co. and Union Electric Co.; Pacific Gas and Electric Co. and Bechtel Corp.; Commonwealth Edison Co. and Public Service Corp. of

Outstanding New

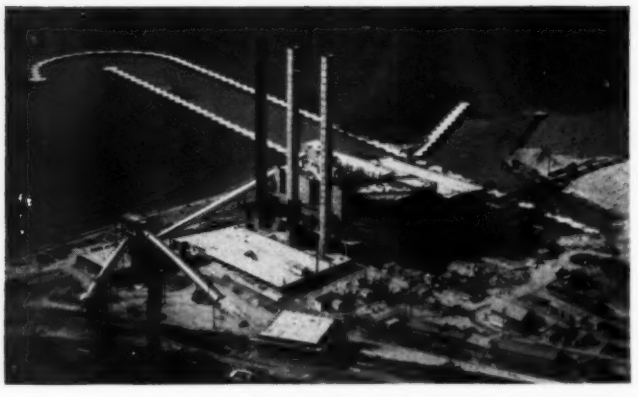


JOPPA STEAM STATION of the Electric Energy, Inc., first station to have an initial capacity as high as 650,000 kw, features four boiler-turbine units operating at a turbine throttle pressure of 1800 psi, primary steam temperature of 1050 F, reheat at 1000 F.



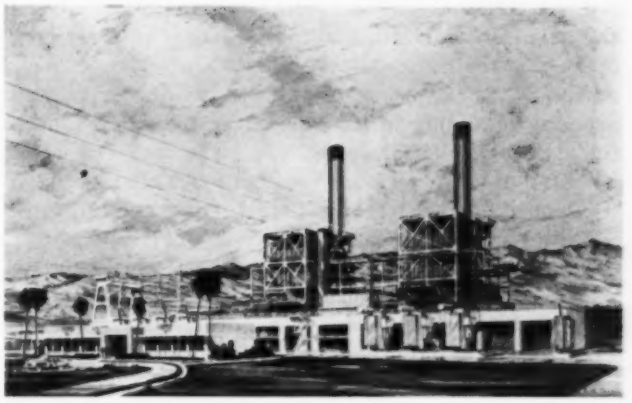
KANAWHA RIVER generating plant of the Appalachian Electric Power Co., an American Gas and Electric System Company, will have two 1,335,000 lb per hr steam generators designed for 2400 psi boiler pressure and 1050 F final steam temperature with reheat to 1050 F.

LAKE CREEK STATION of the Texas Power & Light Co. employs the latest of outdoor type construction. Condensing water comes from an artificial lake created by damming a tributary of the Brazos River. The boiler unit supplies steam at 1350 psi and 950 F to the single 60,000 kw turbine-generator comprising the station's first section. Three more are planned.

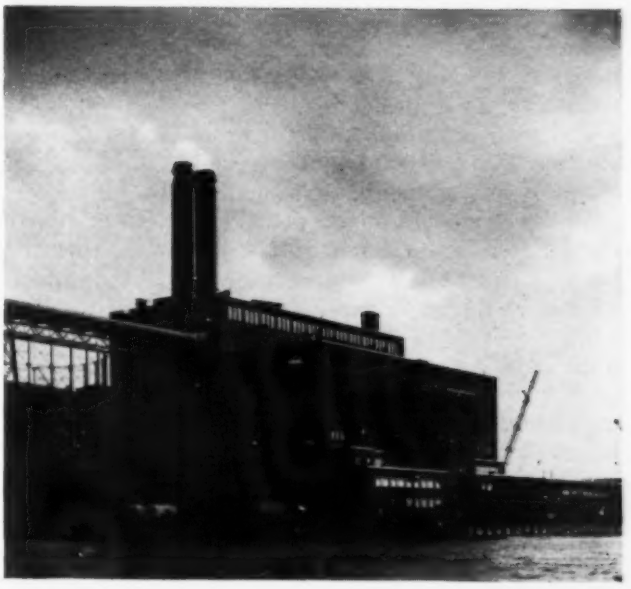


EASTLAKE POWER PLANT of the Cleveland Electric Illuminating Co. went on the line in September of 1953 with an initial 125,000 kw turbine-generator and two duplicates to follow in the spring of 1954. They will all operate at 1800 psi throttle pressure, primary steam temperature 1050 F, reheat, 1000 F.

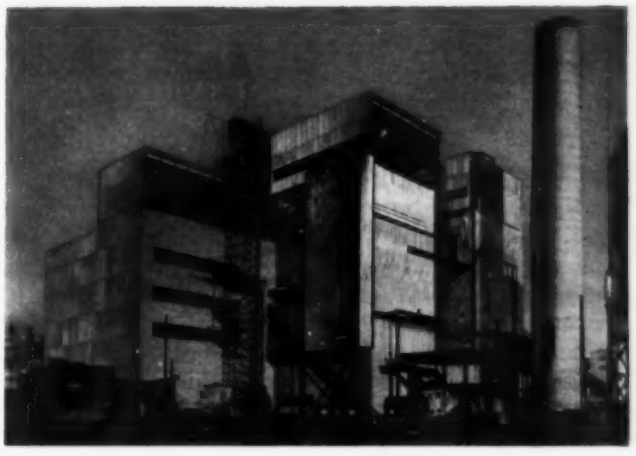
Plants of 1953



ETIWANDA STEAM STATION, second postwar steam station of the Southern California Edison Co., is an excellent example of modern outdoor design. Its initial two steam generators supply two 125,000 kw turbine-generators with steam at 1800 psi, throttle pressure, 1000 F, reheated to 1000 F.



ASTORIA ELECTRIC STATION of the Consolidated Edison Co. of N. Y., first new station on the company's system in twenty five years, makes use of pressurized boilers, 1,200,000 lb per hr steaming capacity, to deliver steam at 1800 psi, throttle pressure, 1000 F temperature and reheat to 1000 F.



AURORA STEAM ELECTRIC STATION of the Minnesota Power & Light Co. started out with two 425,000 lb per hr steam generators furnishing steam at 1350 psi and 955 F to two 44,000 kw turbine-generators. Completion of this station brings the company's interconnected total generating capacity to 347,440 kw, up 106 per cent since World War II.

HENNEPIN STATION of the Illinois Power Co. is the latest addition to this company's remarkable generating capacity growth. Starting in 1947 with a total of 37,000 kw capability the system capacity now totals 519,000 kw. The new 75,000 kw unit employs steam at 1450 psi, throttle pressure, 1005 F primary steam temperature, 1005 F reheat

Northern Illinois—agreed with the AEC to (1) determine the engineering feasibility of designing, constructing and operating dual-purpose reactors to produce fissionable material and power, (2) examine economic and technical aspects of building such reactors, (3) determine estimated research and development, (4) recommend a role for industry in these various phases of reactor technology.

Their studied comments very briefly amounted to:

Dow Chemical–Detroit Edison—Concentrating on sodium-cooled, fast breeder reactors they favored simplified solid fuel elements for the present but suggested more mobile fuels for easier handling and reprocessing. The five reactor arrangements they studied varied from 7500 to 130,000 kw output at a 30 per cent thermal efficiency.

Monsanto Chemical–Union Electric—Studying two sodium cooled, graphite moderated reactors of similar design they reported a 1000 mw heat output unit with sodium ranging in temperature from 650 to 3000 F would generate 3 million lb per hr of 150 psia saturated steam with a 208,000 kw net. The second design studied, a 3000 mw one, gave 8.8 million lbs per hr of 400 psia, 746 F steam and an 834,000 kw net output using the full temperature range of sodium (900 to 300 F); but rejecting heat of sodium below 500 F it evaporated 4.8 million lbs per hr and gave 554,000 kw net.

Pacific Gas and Electric–Bechtel—Employing both a water cooled thermal reactor and a sodium cooled fast reactor of 500 mw output each, the water cooled unit with a heavy water moderator was reported to develop 106,000 kw net with 175 psia, 378 F steam, whereas the much smaller physically sized sodium reactor gave a 145,300 kw net and generated 1,600,000 lbs per hr of 500 psia, 750 F steam.

Commonwealth Edison–Public Service of Northern Illinois—Taking a 350 mw helium cooled, graphite moderated reactor this team found it could get a 46,700 kw net with steam at 265 psia, 525 F and with a heavy-water cooled, heavy-water moderated reactor of 1064 mw output, a 211,500 kw net from 180 psia saturated steam.

Fuels

Mine output of bituminous coal for 1953 was estimated by Keystone Coal Manual to approximate 455 million tons, only about 2 per cent or so below the 465 million ton figure of 1952. The electric utilities raised their consumption up to 112 million tons from the 102 million ton level of 1952. It has been variously estimated that electric utility consumption of coal will go to 130 million tons in 1954 and by 1957 reach 175 million tons.

The atomic energy project plants will burn tremendous amounts. And the TVA is expected to need some 20 million tons annually when all its capacity is at work.

The fuel battle, especially along the Atlantic seaboard, between oil and coal and to some extent gas, continues pretty much unabated. The solid fuel operators are considerably concerned about imports of foreign oil and are pushing for federal controls. Actually most large scale plants are equipped to burn any of the three major fuels and their choice is largely dictated by market price.

Spreader stokers enjoy a wide selection among many industrial plants because of their proved flexibility in handling a range of fuels successfully. They have become somewhat stronger in those industries where by-product solid fuels and waste materials are available.

Equipment Development

At the Fall General Meeting of the AIEE in Kansas City, Mo., a number of excellent reports were given on the status and development of some major power plant equipment. One especially interesting one was that presented by G. V. Williamson, superintendent of power production, Union Electric Co. of Missouri, on the boiler.

Within the past two years Williamson felt boiler design had reached an enviable peak. Today's boiler is now built as a unit to match one turbine and to operate in such exact step with it that the two really work as one unit with amazingly high reliability. In sheer physical size boilers have moved from 125,000 kw giants in 1950 through 180,000 kw and now to 250,000 kw size. The basic design philosophy went through a considerable change to achieve this amazing growth.

In today's boilers the great problem of furnace water walls has been expertly met. The adequate circulation of water in all circuits proved the answer in Williamson's opinion. He particularly cited the pumped circulation boiler whereby circulation to steam rates is reduced from the typical need of 10 to 12 times down to only 4 times the quantity of steam leaving the boiler. This arrangement, partly freeing the designer from the narrow balance between the water in the downcomer and steam-water mix in the tube, permits a wider range in furnace shapes and heights, as well as smaller, thinner water wall tubes.

The advance into still higher temperatures (above 1050 F) and to supercritical pressures, 4500 psig or so, marks a new departure in boiler design. The next few years should see many interesting developments.

E. H. Krieg of Stone & Webster Engr. Corp. reviewed at this same meeting the status of turbine generators. At least eight major types are available. The choice may be dictated by capacity or by costs with the 3600 rpm tandem-compound units usually cheaper but with higher heat rates than cross-compound designs.

Single turbine generator units are on order up to 250,000 kw and 300,000 kw units are ready. If desired 500,000 kw cross-compound units could be supplied. In keeping with the advance into the supercritical steam pressure range one turbine is being built for 4500 psig, with 1150 F throttle temperature and two stages of reheat.

Availabilities of over 92 per cent have been reported over a ten-year period and a number report 96 per cent

Gas Turbines

There are 10 locomotives, 15 electrical power generation units and 35 mechanical drive gas turbine units currently operating or installed in the United States. Essentially all the mechanical drive units are driving gas pumps in gas transmission stations. As of August 1953 these gas turbines had a total operating time of about 170,000 hrs.

Up to the 5000 kw range, residual fuel oil or coal must be used for the gas turbine to obtain commercial desirability. In the 10,000–15,000 kw range where thermal efficiencies reach 25–28 per cent the relatively expensive distillate fuel oil may be justified on the grounds of a lower overall capital investment. But serious practical operating difficulties develop in burning residual fuel oils. The problems seem to be mainly those of nozzle and blade corrosion as well as deposition of material on the turbine blading. All arise from the residual oil ash.

Manpower and Other Operating Costs

In these excerpts from a paper presented at the 1953 ASME Annual Meeting the author sets forth a number of concepts of centralized control and their effect upon operating costs in steam generating stations. He also discusses some of the trends in plant organization and their relation to scientific management.

By V. F. ESTCOURT

Pacific Gas and Electric Company,
San Francisco, California

IN general, plant design, arrangement of equipment, and management policies with respect to operator coverage and training all have a pronounced effect upon operating manpower costs and can be evaluated with reasonable accuracy. First, it is of interest to consider a change in cycle heat rate or a change in the number of shift operators in terms of their equivalent costs, or each in terms of a break-even investment cost. Such a comparison is shown in Fig. 1, wherein these equivalent costs are given for plants ranging in size between 100 and 300 mw and operating at 80 per cent capacity factor. It is clear that the addition of one man per shift would nullify the fuel savings resulting from a gain of approximately 33 Btu per kwhr in cycle efficiency for a 300-mw plant, or nearly 50 Btu for a 200-mw installation. These figures are based upon operating labor costs on the Pacific Coast and the equivalent values will of course be influenced not only by the capacity of the plant but also by prevailing wage rates, the cost of fuel and the plant load factor. Theoretically it requires $4^1/_5$ shift operators to fill one operating position for seven days per week around the clock. When vacations and sick leave provisions are also taken into consideration, as well as possible shift premium pay, the total cost is usually the equivalent of approximately $4^1/_2$ to $4^2/_3$ times the base pay of the payroll classification of each shift operator position. This may be further increased by the need for a training pool to take care of replacements resulting

from resignations or upgrading due to system growth, and the size of this manpower pool is somewhat affected by the number of regular operators on the payroll.

The radical improvements which have been taking place in plant design have been accompanied by a considerable effort to reduce station manpower. However, by far the greater proportion of any success along these lines to date has been the inherent result of the increased size of modern units. On the other hand, without the adoption of centralized control the effect of the size of units upon manpower would not have been so pronounced. By having the major controls centralized in one control room it has been possible to operate two or more large units with only a very small increase in the number of operators above the requirement for one unit.

The benefits from the consolidation of an increasing number of units within the same control room may be very limited or quite substantial, depending considerably upon certain plant managment policies with respect to operator coverage and operator training in relation to a particular plant layout. However, the curves in Fig. 2 illustrate what has actually been accomplished in this respect in certain stations where design and manpower conditions are favorable. The solid line shows the number of installed kilowatts per man in four actual stations with respectively one, two, three, and four units per control room. The four-unit job is nearing construction completion but is not yet in service; therefore the manpower figures are estimated in this instance. The solid line on the chart shows that the kilowatts per man increase from 1700 for one unit per control room to 5200 with four units per control room.

It should not be concluded from the foregoing that the same benefits will continue to accrue as a result of centralizing the controls of more and more units in a single control room. In the first place there are certain offsetting limitations which enter the picture as the controls for more units are added to the same control room almost upon the mathematical basis of the increased distances of equipment from a central control point. There is no true linear relationship between these factors, but increasing the number of units per control room would ultimately bring about the need of additional operators to take care of the remote equipment, thereby reducing or nullifying the benefits of extending the centralized control system. Thus the over-centralization of controls may ultimately lead to diminishing returns.

Another condition may result from concentrating the control of too many units in one control room and that is the danger of some catastrophic situation wiping out the controls of too many large units on a system. This is a very important problem which cannot be overlooked. In connection with our more recent units, considerable thought was given to this matter and the controls were so arranged that the essential individual unit controls are decentralized on panels located at each boiler and turbine unit. The central control room for the four units consists of a so-called master panel arranged so that normal operation of the four units can be handled from a combination bench and vertical panel. This basic hook-up as between the individual unit panels located near the equipment and the central control room master panels is such that operation of the plant could be controlled from these local unit panels even though the entire central control room were wiped out. This does not mean that there is any considerable duplication of instruments and controls; it is rather a functional segregation of controls so that, with the assistance of additional manpower, the controls on the unit panels are satisfactory for manual operation of the station.

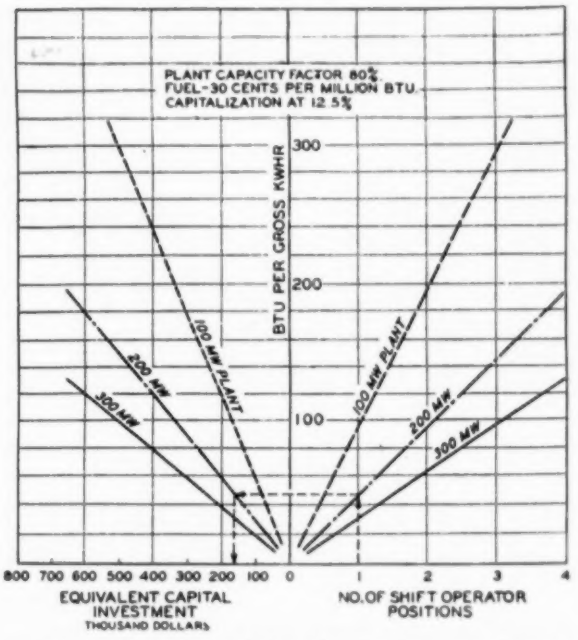


Fig. 1—Equivalent values of plant heat rates, investment and manpower costs

There is a more obvious reason why it is not usually practical to consider the centralized control of more than four units in the same control room. With the trend to larger sized units it is difficult to plan for more than four units at a time in one system location. Therefore in most instances it would hardly be considered desirable to make provision in the design for additional units above four, particularly in view of the possible added investment which might be required in connection with the first four units in order to allow for future addition of other units. On the other hand, there are several very good examples of plants laid out with an initial installation of two large units with provisions for the future installation of one or two additional units of the same or larger size all operated from the one control room.

Effect of Plant Management Policies

One example of the effect of plant management policy upon operating cost relates to shift operator coverage or the scope of duties assigned to each operator. With centralization of controls and substantially increased automatic standby protection of auxiliaries through automatic starting of the duplicate spare, and the general improvement in instrumentation, alarms and controls, it is obvious that plant equipment in general does not require the same amount of operator attention as formerly. Therefore the trend has been to use considerably fewer equipment operators than in the past.

Some companies appear to have taken what amounts to a calculated risk or possibly some sacrifice in reliability by holding the number of control and equipment operators to an almost irreducible minimum for a particular design of station. However, in some instances it has become apparent that the saving in equipment operators

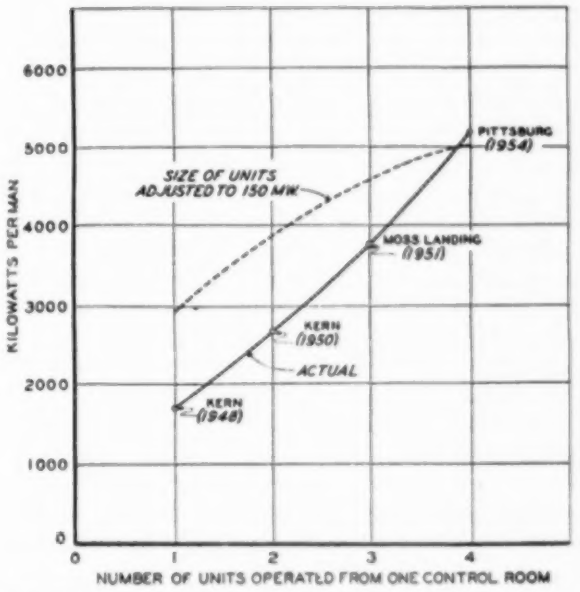


Fig. 2—Effect of number of units per control room upon operating manpower

has been offset in whole or in part by an increased number of control operators with considerably more elaborate and expensive control rooms. Experience indicates that there is usually an opportunity for reducing the work load of operators by a realistic evaluation of their various duties relating to such activities as patrolling and inspecting equipment, logging of instrument readings, etc. A simple example of this will be given.

In stations of older design it was usually the practice to take hourly readings of all instruments. With the increased complication of modern power stations there has been not only a substantial increase in the amount of instrumentation but considerably more use has been made of recording instruments. The question then arises as to whether recording instruments need to be read by the operator at regular intervals. A time honored theory has been that the only guarantee the operator is keeping himself familiar with all of his plant conditions is to require him to log all of the important instrument readings at frequent intervals regardless of whether they are recorded or not. Although this is still a good basic approach, the considerable increase in instrumentation introduces the problem of overloading a limited number of shift operators so that they do not give sufficient attention to overall operation of the station. This is particularly true where the total manpower has been reduced to a figure corresponding to, say, 3500 kw per man or higher for two or more units of not less than 100,000 kw capacity. Studies which were made in some of our larger stations have resulted in the reduction in frequency and number of regularly logged instrument readings by as much as 65 per cent without materially affecting the assurance that the operators are being kept closely in touch with the performance of each item of equipment throughout the day.

By carefully analyzing and evaluating the various duties of the shift operators in relation to the functional components of the plant, it is possible to determine with reasonable accuracy the work load on each man under both normal and upset conditions of operation. With this information we can arrive at a so-called austerity factor rating for a particular plant. At the risk of over-simplifying the problem, the method can be illustrated in a very general way by assuming that two modern reheat units each with one gas and oil fired boiler and having a capacity of 100 or 150 mw, with a shift crew of 5 men, would have an austerity factor rating close to 80 or 90 per cent depending considerably upon the plant layout and other factors involving basic operating conditions and plant management policies. It might further be considered that the addition of 4 or 5 more operators to each shift would reduce this austerity factor to zero, and intermediate figures may be obtained by interpolating between these two extremes. However, changes in the design of the plant by more judicious application of instrumentation and controls and improvements in layout for functional simplicity could so reduce the work load on the operators as to bring about an appreciable change in this austerity factor rating.

Differing Concepts of Centralized Control

The term "centralized control" has been abused by its rather loose application in somewhat the same manner as the popular conception of "stainless steel" when applied as a generalization for any steel containing chromium. Some idea as to the difference in philosophies upon which the designs of centralized control jobs are based may be obtained by comparing the total number of plant operators per shift required in each instance. In the recent past, these have ranged from a minimum of six to a maximum of seventeen per shift for two units per control room. This wide disparity of manpower requirements represents a difference of approximately $200,000 per year in payroll or a break-even equivalent capital investment of approximately $1,600,000.

In so far as we are aware, the first attempt to operate a large high-pressure steam generating plant from a central control point was made at the Holland Station in 1930. This plant, now renamed Gilbert Station, is arranged without a dividing wall between the turbine and boiler areas and is operated from a single group of control panels.

Typical examples of subsequent jobs specifically designed for centralized control are as follows:

1. Oswego, Niagara Mohawk Corporation. Initial operation in 1940.
2. Avon, Pacific Gas and Electric Company. Initial operation in 1940.
3. Martinez and Oleum, Pacific Gas and Electric Company. Initial operation in 1941.
4. Tidd, American Gas and Electric system. Initial operation in 1945.

There may have been other examples, but the above-mentioned jobs were among the first applications of centralized control to high pressure steam plants of any considerable size and may be considered as fairly typical of the early developments in centralized control layouts.

The type of control room layout which is feasible for a particular plant is considerably influenced by prevailing policies with respect to operator coverage. Broadly speaking, shift operators fall into two categories or some combination thereof. The men assigned to the control room are usually known as control operators as distinct from equipment operators who actually patrol and operate the individual pieces of equipment locally. Some utilities make a rather definite distinction between these

two categories of operators so that the duties of the control operator are specifically confined to the operation of the controls in the central control room; equipment operators, on the other hand, have the exclusive duty of patrolling equipment and actually handling valves and performing other physical operations relating specifically to the equipment as distinct from the controls. More or less of a compromise has been adopted by others wherein one of the control operators may occasionally leave the control room in order to perform certain duties relating to the equipment itself, thereby assisting the equipment operator when necessary. There is still a third policy wherein the control operators are specifically trained to perform equally well the double functions of control and equipment operators.

Layouts of Control Rooms

Although varying considerably as to detail, control room layouts may be broadly classified into the following three basic types:

1. Completely isolated and remote.
2. Semi-isolated and centrally located.
3. Open and centrally located.

In the first category listed above are included those control room layouts which provide complete isolation from the plant equipment by means of a fully housed soundproofed room. This appears to be the most popular arrangement at the present time. There are some instances of this type of control room wherein it is centrally located with respect to operation but the complete isolation makes it relatively unimportant whether it is in a central location with respect to turbines and boilers or remotely located in a corner of the building or even on the roof of the plant, as is the case with at least one company.

In the second category, the semi-isolated and centrally located control room is one which is completely enclosed and soundproofed, but which gives the appearance of only semi-isolation due both to its proximity to major equipment with adequate access doors and the use of considerable glass paneling to provide a certain amount of visibility with respect to major equipment. The functional difference between the completely isolated and semi-isolated type of control room is not very great. The number and type of shift operators required in each instance is approximately the same and it might be safe to say that a choice between the two types can be based largely upon considerations of investment cost and personal preference for the particular station. Good success is reported by some companies with layouts which rely almost entirely upon remote control of all equipment operation including the starting up and shutting down of major units.

In either of these two arrangements control operators are usually assigned on a unit basis. Thus, in a station consisting of two main units, one half of the control room contains one or more control panels with all of the necessary controls and instrumentation for the mechanical operation of one of the units. One operator is assigned to the operation of such a panel. The other side of the control room consists of a duplicate set of panels for the other unit, and usually there is a separate group of generator and electrical panels which may be supervised by a third man. In addition to these control operators there are generally between two and four equipment operators located around the station to patrol the various items of major equipment and auxiliaries. A watch engineer or shift foreman would complete the complement of shift operators making a total of from five to eight men per shift for two main units.

In a certain sense this represents the ultimate of the so-called unit system concept wherein not only is the boiler-turbine combination considered as an isolated unit, but there are also unit control panels and unit operators. However, some utilities have backed away from this extreme policy of unit operators and are endeavoring to get along without the third man by having the other two men consolidate their duties to some extent. This measure of economy can be accomplished without greatly impairing operating reliability in the case of base load stations with few or no local distribution circuits and only a few transmission outlets, and is an example of what can be accomplished by the application of a higher factor of austerity in shift manpower coverage.

The third category referred to above applies to a control room which is not only centrally located with respect to major equipment but is also open on one or more sides in order to provide unrestricted movement of operators between the controls and the various items of major equipment and principal auxiliaries. This type of layout presupposes the use of combination control and equipment operators who are trained to handle the controls and operate the principal electrical and mechanical equipment, most of which are located at the control room level. Thus it should be clear by now that there is a fairly well defined correlation between the type of control room layout, the basic panel arrangement within the control room, and the type of operators.

In order to carry this concept to its logical conclusion, careful consideration must be given to the plant layout with respect to the location of various auxiliaries such as boiler feed pumps, evaporators, etc., so that they are readily accessible from the control room. Fire doors are usually provided to isolate the control room in a major emergency. This open type arrangement not only allows the operators freedom of movement between the control room and the principal equipment but also serves the purpose of allowing a predetermined level of normal machinery noises in the control room except in the soundproofed operator booth which is provided for the purpose of efficient communication and necessary desk work. Control operators who also perform the functions of equipment operators, in addition to their duties as push-button operators, must be reasonably noise conscious if they are to do an intelligent job of operating the equipment.

For maximum effectiveness of this arrangement, it is necessary to obtain a compromise between compactness in the panel arrangement and good readability of instruments, so that the operators are able to see the principal instruments at a reasonable distance as they move about in connection with their diversified duties. In this respect the situation is exactly the opposite of what is required in the isolated unit-type of control room. It should also be understood that the location of the control room in a central position with respect to boilers, turbines and important auxiliaries is not so much for the purpose of seeing them as it is to provide accessibility for those equipment operations which require the personal

attention of the operator who, in this type of layout, performs the dual functions just described.

The necessary compactness and functional simplification are achieved by arranging instruments and controls in accordance with a master panel system as distinct from a unit system. On the master panel are assembled the principal instrumentation and controls for a minimum of two and a possible maximum of four main units. It has been learned through many years of close observation that certain specific instruments and controls are required to operate the plant safely under average day-to-day conditions, and these represent only a relatively small percentage of the total. Therefore, the essential instruments for, say, four main units can be grouped on one master panel which is no longer than a panel containing all of the instruments for a single unit. A large proportion of the special instrumentation and controls for individual equipment are located on panels which may or may not be in the control room or even within sight of the operator from the control room. No operators are located permanently at these remote panels. A number of utility companies have adopted this idea of a master panel and in at least one instance it has been designated as a flight panel.

This functional arrangement of the master panel greatly relieves the psychological strain so that usually a single operator can handle the controls on a master panel for three or four units about as easily as a single operator can take care of the unit type of panel with its considerable concentration and complexity of instrumentation and controls, many items of which are seldom used. The latter frequently include long rows of neatly arranged control devices all identical in appearance and uniformly spaced on the panel so that it is impossible to identify them without reading the nameplates. On the other hand, the tremendous advantage of the inherent diversity factor in the master panel arrangement becomes most apparent in the event of upset conditions. Since it is usually the case that trouble does not occur simultaneously on all of the three or four units, this diversity of work load with respect to individual units materially lightens the burden upon the operators who are assigned to such a group of units. Furthermore, the problem of the shift foreman, in coordinating the overall operation of three or four units, is greatly simplified by reason of this functional centralization of important instrumentation and operating activity.

In Figure 2, the effect upon manpower of the number of units per control room has been illustrated. These curves apply to actual stations of a basic design conforming to the philosophy of this third category of centralized control. It is important to emphasize this point because substantially different results might be obtained with other arrangements of centralized control and differently trained operators. As an example, we were advised a year or so ago by the designers of a plant then under construction with a single control room for four units that, although there was the potential possibility of a labor saving with four units per control room instead of two, there was no certainty that it would materialize and at best it might amount to one operator per shift. This is fundamentally true with so-called unit panels and unit operators, because each additional pair of units calls for substantial duplication of shift operating personnel.

Although this third category of centralized control philosophy appears to favor relatively low operating labor costs, it should be clear that certain conditions are essential for its satisfactory application. Without doubt the initial training of the type of operator required is more costly and its success is dependent largely upon the background and attitude of both first level supervision and top plant management. It is unrealistic to advocate a particular philosophy of control room layout and panel arrangement unless all of the local conditions with respect to available personnel and plant management policies are known in intimate detail. The proper solution in each instance requires painstaking attention to the functional and human realities of the particular job.

The Changing Scene in Plant Organization

The discussion of these various operating and management problems in the light of the rapidly advancing technology in this field naturally leads to a consideration of the changing scene with respect to the type of plant organization required. In the relatively crude designs of thirty years ago, the operating problems were so simple that an Orsat and plenty of willing hands were about all that were necessary to obtain the maximum efficiency of such inherently wasteful cycles. The impressive gains in thermal efficiency which have already been made since that time are to be surpassed in the immediate future as a result of still higher steam temperatures and pressures with multiple reheat. This will be accompanied by a further growth in the complexity of design and operating problems, and it may be anticipated that the latter will tend to increase in greater proportion with each major advance in basic design.

It is therefore important to examine the progress we are making in maintaining a plant organization which can achieve, with a minimum payroll, the full measure of the potential economic gains inherent in these technological improvements. First, it should be observed that the practical operator of today's power plants, when properly trained, represents an impressive advance in intellectual stature and know-how as compared with the manpower of thirty years ago. He takes pride in the rapid progress being made in his chosen field and fully appreciates that, in our expanding economy, these advances are reflected in greater employment and a general elevation of his economic and social position.

It is logical that power engineering activity in the past was concentrated largely in the creation of more efficient designs. As a direct result of this progress in design, a gradual evolution has been taking place so that now it is becoming increasingly urgent to place greater emphasis upon the technical problems of operation and management. Furthermore, the art is advancing so rapidly and the potential fuel savings are so great that considerable additional expense can sometimes be justified in overcoming substantial initial difficulties with pioneer developments. It therefore follows that the manufacturers are dependent as never before upon the cooperation of the utilities in testing and analyzing untried designs in the field and in obtaining their advice and assistance in overcoming defects which can only be discovered in actual operation. As many of us know from actual experience, such cooperative effort has frequently been an important factor leading toward major improvements in basic equipment design.

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MATERIALS · ENGINEERING · APPLICATION

Experiences with Filming Amines in Control of Condensate Line Corrosion

Attributing condensate line corrosion chiefly to the presence of carbon dioxide in the steam and water, various methods of minimizing boiler feedwater alkalinity are discussed, especially the employment of filming amines. This new approach to the problem is based on the deposition of a nonwettable film on the metal which is impervious to penetration by the condensate. Field results under various conditions are reported.

By H. L. KAHLER* and J. K. BROWN†

THE corrosion problem caused by the presence of carbon dioxide in steam and condensate is well recognized. The principal source for the presence of carbon dioxide in steam and condensate is bicarbonate and carbonate alkalinity of the boiler feedwater. Under boiler temperature and pressure conditions, these forms of alkalinity decompose, releasing carbon dioxide with the steam. Grooving of condensate lines and failure at threaded joints, as shown in Fig. 1, result from carbon dioxide attack. Pitting occurs when oxygen is present along with carbon dioxide.

Fig. 1—Example of failure at threads due to carbon-dioxide corrosion

Because of the severe maintenance problem created by steam and return line corrosion, many methods for corrosion control have been applied. External treatment measures that minimize boiler feedwater alkalinity will reduce the carbon dioxide content of the steam. The lime–soda and lime–gypsum softening processes will reduce alkalinity to the range of 50 to 60 ppm, principally in the carbonate form. With normal softener balances, the expected carbon dioxide content of the steam will approximate 17 to 21 ppm, when employing 100 per cent makeup. Use of hot lime–hot ion-exchange permits a further decrease in carbon dioxide by minimizing the carbonate alkalinity of the softener effluent. By acid treatment of a sodium-zeolite effluent, alkalinity may be reduced to the range of 10 to 20 ppm and similar results can be produced by combination hydrogen-sodium zeolite softening. A recent development has been alkalinity reduction by chloride-regenerated resins which exchange chloride for alkalinity in the softener effluent.

It is possible by selection of the proper external treatment processes to produce a minimum carbon dioxide content of the steam, in the range of approximately 5 ppm CO_2, when using 100 per cent makeup water. At this level of carbon dioxide, corrosion usually is not serious. However, at points of condensation and in condensing equipment where carbon dioxide can concentrate, serious corrosion results from even this small carbon dioxide concentration of the steam. Where oxygen may be introduced into the condensate through vacuum pumps and leakage, a serious corrosion problem develops even with adequate preparation of the boiler feedwater.

Internal treatment measures that have been applied to this problem include the use of alkalies and polyphosphates which have been fed to the steam in the form of a water solution. Neither alkalies nor polyphosphates have been very successful in combating carbon dioxide corrosion and the addition of such inorganic solids to the steam is objectionable for the same reasons that carryover of boiler water solids is undesirable.

Ammonia has been successfully employed for control of carbon dioxide corrosion and iron pickup in central stations with low percentage makeup water and low carbon dioxide concentrations in the steam. While a reduction in corrosion of ferrous metals can be secured, copper- and zinc-bearing metals can be seriously corroded, particularly when oxygen is also present and there is opportunity for ammonia to concentrate. Because of the higher carbon dioxide concentrations usually found in industrial plants, and consequent higher ammonia requirements, the problem of copper attack limits the application of ammonia.

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Neutralization of carbon dioxide can safely be accomplished by certain volatile amines such as cyclohexylamine ($C_6H_{11}NH_2$), morpholine (C_4H_9NO), and benzylamine ($C_6H_5CH_2NH_2$). These amines, when fed to a boiler, volatilize with the steam and combine with carbon dioxide in the condensate to neutralize its acidity. These amines in low concentrations are not corrosive to copper- and zinc-bearing metals. Control of treatment is usually based on feeding sufficient amine to raise the pH of the condensate to the neutral zone or above. Satisfactory reduction of carbon dioxide corrosion has been obtained with the use of the neutralizing amines in the absence of oxygen.

The neutralizing amines have two principal disadvantages. They provide no protection against oxygen attack. Secondly, treatment costs may be relatively high since they function by neutralizing the acidity of carbon dioxide and are required in direct proportion to the carbon dioxide content of the steam.

Filming Amines

Introduction of filming amines a few years ago provided a new approach to the problem of steam and condensate return-line corrosion (1). It is the purpose of this article to report on the field results secured by the application of the filming amines under a variety of plant conditions over extended periods of time.

The filming amines function by a new principle, based on the deposition of a film of long chain polar amines on the metal surfaces. The filming amines in the concentrations employed do not neutralize carbon dioxide (1). Instead they function by forming on the metal surfaces contacted an impervious nonwettable film that acts as a barrier between the metal and the condensate, thus protecting against both oxygen and carbon dioxide attack. When the filming amines are adsorbed on the metal surface, water will not wet that surface; hence the corrosives, carbon dioxide and oxygen, cannot come into intimate contact with the fresh metal surface to corrode it. The film formed through the use of these amines is of substantially monomolecular thickness and does not increase in thickness with continued treatment. The amine will penetrate old corrosion products present on a metal surface and deposit a protective film on the metal. While continuous treatment is advised, the adsorbed film on the metal surface is quite durable and is not removed during short periods of discontinued treatment.

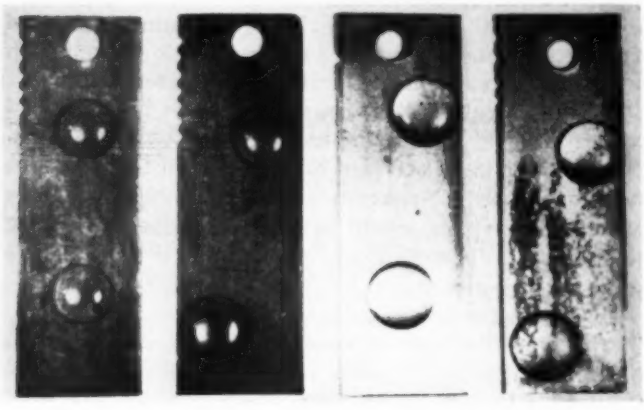

Fig. 2—Steel and brass specimens after exposure to condensate treated with filming amines showing nonabsorption of water

In Fig. 2 the two steel specimens on the left and the two brass specimens on the right after 30 days exposure in a condensate system treated with filming amines show drolepts of water assuming a spherical form.

Both specimens in Fig. 3 had a few drops of water placed on their surfaces. That on the right, labeled "61," had been exposed to condensate treated with filming amines, causing the water to assume droplet form, whereas that on the left, "35," was untreated and did not repel the water which spread over the surface.

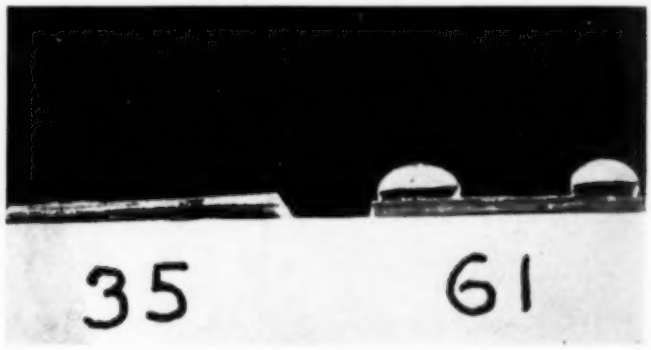

Fig. 3—Untreated specimen on left and treated specimen on right, showing absorption and nonabsorption, respectively

The results reported here have been secured through the use of octadecylamine ($C_{18}H_{37}NH_2$). This insoluble amine is processed and emulsified so that dispersion and feeding from water solutions is possible. This dispersed form of the filming amine is applied to steam and return-line corrosion problems by feeding the solution with a small chemical pump to the main steam line at a point where it will be well mixed with the steam. The material is readily dispersed with the steam and is carried through the steam and condensate lines, forming a nonwettable protective film on the metal surfaces, as described in U. S. Patent 2,460,259 (2).

Unlike neutralizing amines that must be fed in direct proportion to the carbon dioxide concentration of the steam, a feeding rate of 15 to 30 ppm of the commercially dispersed filming amine is usually sufficient to establish and maintain the desired corrosion-resistant film on the metal surfaces. Consequently, except at very low carbon dioxide concentrations, the filming amine treatment is considerably more economical than use of the neutralizing amines.

Evaluation of plant results has been secured through careful records of maintenance and line replacement costs and also from the exposure of test strips at representative points in the condensate system. In general, test strips have been exposed in duplicate over two- and four-week intervals, both before and after applying treatment. Fig. 4 illustrates a typical test specimen bypass installation.

Summary of Plant Data

A summary of data obtained from plants of widely varied operating characteristics is given in Table 1. It will be noted that the protection secured with the filming amine ranged as high as 99 per cent with carbon dioxide

concentrations in the group of plants listed varying from 4 to 160 ppm. The corrosion rate shown by the test specimens is not directly proportional to the carbon dioxide content of the steam in each plant. Flow rate past the test specimens, temperature, and oxygen concentration vary in individual cases. However, the percentage protection secured is an accurate value since the test specimens were exposed at the same point in the system and under the same operating conditions, both before and after the application of the filming amine.

A supplementary benefit secured from the filming amines is their ability to promote dropwise condensation of the steam. Dropwise condensation provides much more efficient heat transfer than film condensation. The nonwettable film formed by the amine on heat-exchange surface assists in this more efficient dropwise condensation. In many cases, treatment of the steam with the filming amines can be justified from the increased heat-

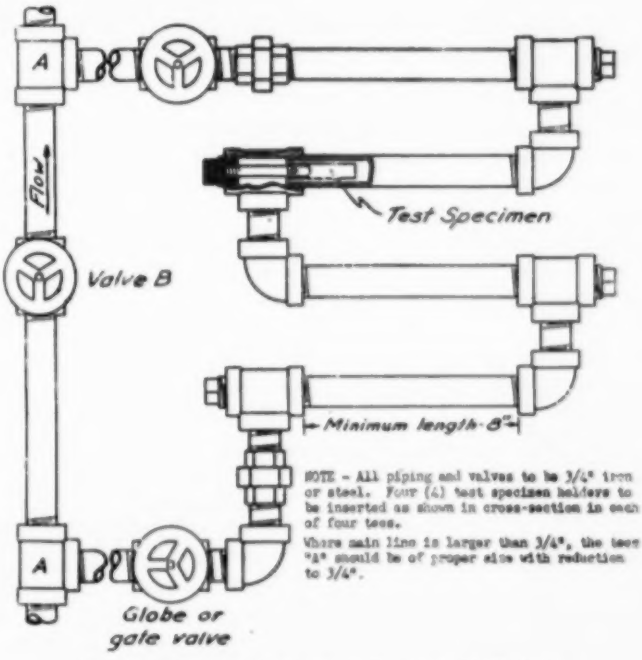
A
Flow
Test Specimen
Valve B
Minimum length 8"
A
Globe or gate valve
NOTE - All piping and valves to be 3/4" iron or steel. Four (4) test specimen holders to be inserted as shown in cross-section in each of four tees.
Where main line is larger than 3/4", the tees "A" should be of proper size with reduction to 3/4".

Fig. 4—Bypass for test specimen installation

transfer efficiency alone. For example, in certain paper-mill drying operations, improvement of 5 to 10 per cent in efficiency has been obtained.

Another benefit secured with the filming amines has been the removal of old corrosion products from lines, traps and heat-exchange surfaces. The filming amine possesses a definite cleaning effect which can be controlled by variation in the rate of amine feed. In badly fouled systems, where it is desirable to remove old iron-oxide deposits gradually, the filming amine has been fed initially at the low feed rate, such as 5 ppm, and then gradually increased as the deposits were removed.

Examination of test specimens exposed with filming amine treatment, both in plant practice and in pilot plant work, has indicated no tendency for corrosion to concentrate in the form of pitting. It is believed that the filming amine functions as an adsorption inhibitor and, with reasonably continuous treatment, maintains complete coverage of the metal surface, thus affording no opportunity for localized attack.

Toxicity tests on the commercial filming amine, prepared from refined (redistilled) octadecylamine have shown that even at 100 times the normal concentration used, the material is not toxic to laboratory animals. No undesirable dermal effects are noted by contamination of bandages, dressings, etc., at 500 times normal concentration. Food plants, hospitals, textile plants and all types of industry employing steam in direct contact with the product have employed filming amines without adverse effect for several years.

TABLE 1 — TEST SPECIMEN DATA FROM 50 PLANTS OF VARIED CHARACTERISTICS

Type Industry	Boiler Pressure psig	% Returns	CO_2 in Steam, ppm	Lbs. Steam Produced Per Day	Ave. Penetration-in/yr. Before Filming Amine Treatment	Ave. Penetration-in/yr. After Filming Amine Treatment	% Protection
Abrasives	150	75	49	4,000,000	0.0028	0.0028	95
Aircraft	110	25	50	400,000	0.0241	0.0002	99
Appliance Mfg.	125	50	103	500,000	0.0320	0.0031	90
Arsenal	100	55	90	1,000,000	0.0072	0.0007	90
Batteries	75	40	14	125,000	0.0195	0.0005	98
Brewing	125	75	27	300,000	0.0562	0.0005	99
Carton Mfg.	400	40	12	2,000,000	0.0070	0.0017	76
Cement	175	10	20	2,500,000	0.0062	0.0010	74
Chemicals	335	70	14	550,000	0.0590	0.0022	95
Dairy	120	75	70	500,000	0.0151	0.0004	97
Electrical Mfg.	125	55	100	1,000,000	0.0120	0.0041	66
Electrical Mfg.	85	80	54	200,000	0.0550	0.0059	89
Electronic Mfg.	100	44	57	150,000	0.0500	0.0004	99
Felt	100	15	40	150,000	0.0110	0.0016	85
Fiberboard	440	55	28	750,000	0.0441	0.0011	97
Food	120	40	100	100,000	0.0043	0.0012	72
Food	125	50	61	150,000	0.0081	0.0012	85
Hospital	125	60	52	101,000	0.0056	0.0800	85
Linoleum	150	50	20	100,000	0.0258	0.0002	99
Machinery	150	50	25	1,000,000	0.0201	0.0017	95
Machinery	100	45	29	950,000	0.0168	0.0019	89
Metal Fabrication	75	65	80	200,000	0.0110	0.0004	96
Metal Fabrication	120	50	80	100,000	0.0690	0.0080	88
Metal Fabrication	125	50	45	3,000,000	0.0052	0.0010	81
Natural Gasoline	180	40	100	800,000	0.0096	0.0005	97
Natural Gasoline	220	60	0	1,000,000	0.0073	0.0005	93
Oil Refining	200	10	150	1,300,000	0.0650	0.0040	94
Oil Refining	260	0*	85	25,000,000	0.0855	0.0011	99
Oil Refining	260	15	75	1,200,000	0.0890	0.0056	94
Paper	400	85	5	1,400,000	0.0035	0.0005	86
Paper	250	10	12	4,000,000	0.0510	0.0022	96
Paper	600	15	15	2,000,000	0.0089	0.0015	83
Plastics	100	60	57	500,000	0.0047	0.0005	94
Pottery	125	50	15	250,000	0.0360	0.0085	76
Research Lab.	90	80	11	180,000	0.1530	0.0006	99
Roofing Matls.	600	70	10	1,500,000	0.0213	0.0043	80
Rubber (synthetic)	400	10	25	15,000,000	0.0150	0.0026	81
Rubber Products	100	50	27	500,000	0.0125	0.0028	77
Rugs	175	30	29	750,000	0.0095	0.0005	97
Rugs	60	40	95	40,000	0.0845	0.0029	88
Shoes	200	55	68	1,500,000	0.0650	0.0038	94
Steel	150	10	21	800,000	0.0491	0.0026	95
Textile	125	60	20	800,000	0.0070	0.0017	76
Textile	150	50	45	140,000	0.0172	0.0045	75
Textile	250	40	85	1,400,000	0.0105	0.0005	95
Tile	125	30	112	250,000	0.0090	0.0004	92
Tires	195	25	73	1,000,000	0.0045	0.0002	95
University	125	45	47	500,000	0.0260	0.0004	98
Utility	285	87	4	6,400,000	0.1350	0.0025	98
Wood Products	145	40	15	500,000	0.0109	0.0005	95

* All low-pressure condensate returned as make-up to high pressure boilers.

Maintenance Data

Usually it is not possible in an individual plant to relate directly the data secured from test specimens with the actual cost of corrosion and the savings possible through correction of the corrosive condition. However, comparison of maintenance costs before and after the application of treatment will indicate the actual savings secured. A few typical plants will be discussed.

A small eastern plant, operating at 150 psi and producing 300,000 lb of steam per day, employs sodium-zeolite softening of a fairly high bicarbonate makeup water. The carbon dioxide content of the steam averages 40 ppm. Continual maintenance was required because of failure of condensate lines from steam kettles and unit heaters. Exposure of specimens before and after application of the filming amine indicated approximately 80 per cent reduction in corrosion. Maintenance records at this plant showed that the use of filming amines resulted in an annual savings of approximately $8000, including both materials and labor, over and above the cost of treatment.

An eastern aircraft manufacturing plant, operating at 125 psi, with makeup varying from 45 to 75 per cent of the boiler feedwater, was plagued with excessive corrosion throughout an extensive return-line system. Carbon dioxide in the steam varies from 14 to 27 ppm. A yearly expenditure of $1200 for filming amine treatment resulted in an annual savings of $7300 in material and labor in return-line maintenance. It is estimated that an additional savings of 6000 lb of steam per hour was secured principally by elimination of blow-by of steam past the traps, caused by corrosion and clogging of the seats with corrosion products (3).

Table 2 summarizes test specimen data from this plant and is particularly interesting since the increased protection secured over several months time is shown. As will be noted, the corrosion rate for Building No. 2 was not excessive even before treatment. The filming amine reached this point in the system quite quickly and promptly reduced the corrosion rate to a negligible value. Tests conducted five months later showed essentially the same results.

TABLE 2 - TEST SPECIMEN DATA SHOWING INCREASED PROTECTION OVER A 5 MONTH PERIOD

Test Conditions	Time of Exposure, Weeks	Average Penetration, Inches/Year Building Number 2	Combined Returns
Before treatment	2	0.0020	0.0250
	2	0.0015	0.0300
	4	0.0015	0.0205
	4	0.0010	0.0215
Treatment started two weeks before specimens exposed	2	0.0001	0.0078
	2	0.0005	0.0084
	4	0.0001	0.0080
	4	0.0001	0.0081
Specimens exposed after five months of treatment	2	0.0001	0.0005
	2	0.0005	0.0005
	4	0.0002	0.0001
	4	0.0005	0.0000

Specimens exposed on the combined returns showed a high corrosion rate prior to treatment. The steam and condensate systems at this plant are quite extensive and while an immediate improvement was noted on first applying the filming amine, the full effects of treatment were noted on the samples exposed five months later. The specimens exposed in the combined returns probably did not receive the full benefit of the filming amine treatment until all of the long lines acquired an amine film. It was believed, since the system was badly corroded, that some amine was adsorbed by iron oxide deposits until gradually all of the surfaces became saturated.

A plant generating 5,000,000 lb of steam daily at 150 psi conducted a thorough study of the effectiveness of the filming amine by first feeding the amine to only one small section of the plant and observing results through the installation of test specimens. On tests extending over several months, corrosion protection values as high as 98 per cent were shown. After application of the filming amine to the entire steam system, maintenance records indicated an annual savings of approximately $40,000.

A mid-western plant, sprawling over 130 acres and with a building heating volume of 90,000,000 cu ft suffered high maintenance cost due to failure of unit heaters, traps and piping. At this plant, separate tests were conducted with the addition of phosphates to the steam, with neutralizing amines and with filming amines. Filming amines were adopted as a treatment based on test specimen data. For the portion of the system for which maintenance data were available, unit heater and condensate line maintenance decreased $5,500 annually (4).

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(2) Kahler, H. L., U. S. Patent 2,460,259.
(3) Elliott, E., and Gaughan, P. J., *Power Engineering*, **55**, 104–9 (Aug. 1951).
(4) Mierendorf, G. A., *Proc. American Power Conf.*, **14**, 453–8 (1952).

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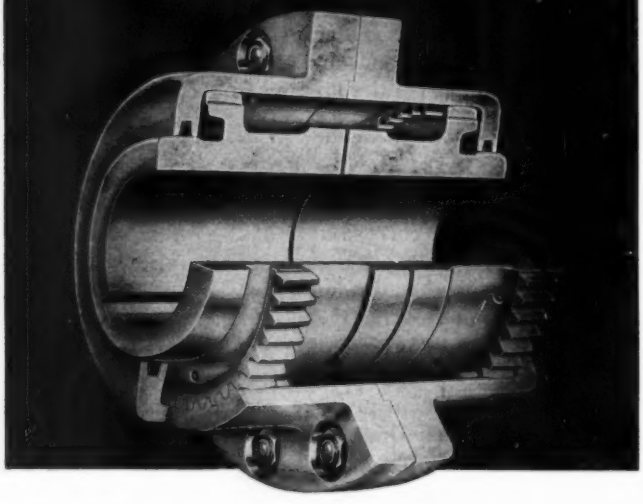
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Flyash Gaining Acceptance As An Admixture In Concrete

Preparation of a tentative specification for flyash as an admixture in concrete took a major step forward at the Fall Meeting of Committee C-9 on Concrete and Concrete Aggregates of the American Society for Testing Materials, at Purdue University. A draft of the proposed specification was reviewed in detail by the subcommittee and the final draft will now be circulated to the subcommittee for letter ballot. In view of the changes in the final draft of the specification, it will now be necessary to rewrite the Test Method for Flyash as an Admixture for Portland Cement Concrete, (C 311 - 53 T). The proposed specification and the revised tentative will be presented to the parent Committee C-9 simultaneously for recommendations as to adoption as ASTM "Tentatives" of the Society.

Significant developments were reported in the study of chemical reactions of aggregates and concrete, and the subcommittee dealing with this subject presented a draft of a proposed tentative method of test for potential volume change of cement-aggregate combinations.

"Significance of Tests of Concrete and Concrete Aggregates", Special Technical Publication 22, sponsored by Committee C-9, has been very much in demand, and copies of the last edition have now been exhausted. Heeding this demand, the committee accepted a proposed outline for an entirely new edition which will be expanded to include the significance of properties, as well as tests of concrete and concrete aggregates. Suggested authors have been assigned, and the development of this project will proceed rapidly, with the expectation that it may be completed early in 1955.

Instrument Conference

The Instrument Society of America will hold its 9th Annual Regional Conference on Wednesday, February 4, 1954 at the Hotel Statler in New York City. Four separate groups, namely, power, process, medical and aviation, will present papers on "Progress in Measurement." The banquet speaker will be Dr. S. A. Goudsmit, Senior Scientist, Brookhaven National Laboratory, who will speak about his work in the atomic energy field.

The following papers are expected to be of interest to engineers in the steam power field:

1. "Observations of Air Flow and Steam Flow Measurements," by A. T. Jorgenson, manager of electric production of Long Island Lighting Company.
2. "The Effect of Measurement Errors on Plant Performance Tests," by Dr. S. Baron, staff mech. engr., head of Heat Balance Department of Burns & Roe, Inc., New York.
3. "Gas Sampling Techniques for O_2 and CO_2 Recording," by D. Burns, chief engineer of Hays Corporation.

Bimetallic Transition Pieces Gain Acceptance

Public Service Electric and Gas Co. at its 1500 psig, 1050 F, Sewaren Station was the first to employ special bimetallic Kelcaloy transition pieces between chrome-moly main steam piping and stainless steel valves. Then Consolidated Edison of New York selected Kelcaloy pieces for Hudson Avenue Annex. The basic reason behind their action was an understandable reluctance on the part of designers to join by butt welding two metals of widely varying thermal coefficients of expansion. The ferritic $2^1/_4$ per cent chrome, 1 per cent moly and the austenitic type 347 steels have a difference of about 30 per cent in their thermal coefficients.

The transition piece eliminates the need to weld these metals together.

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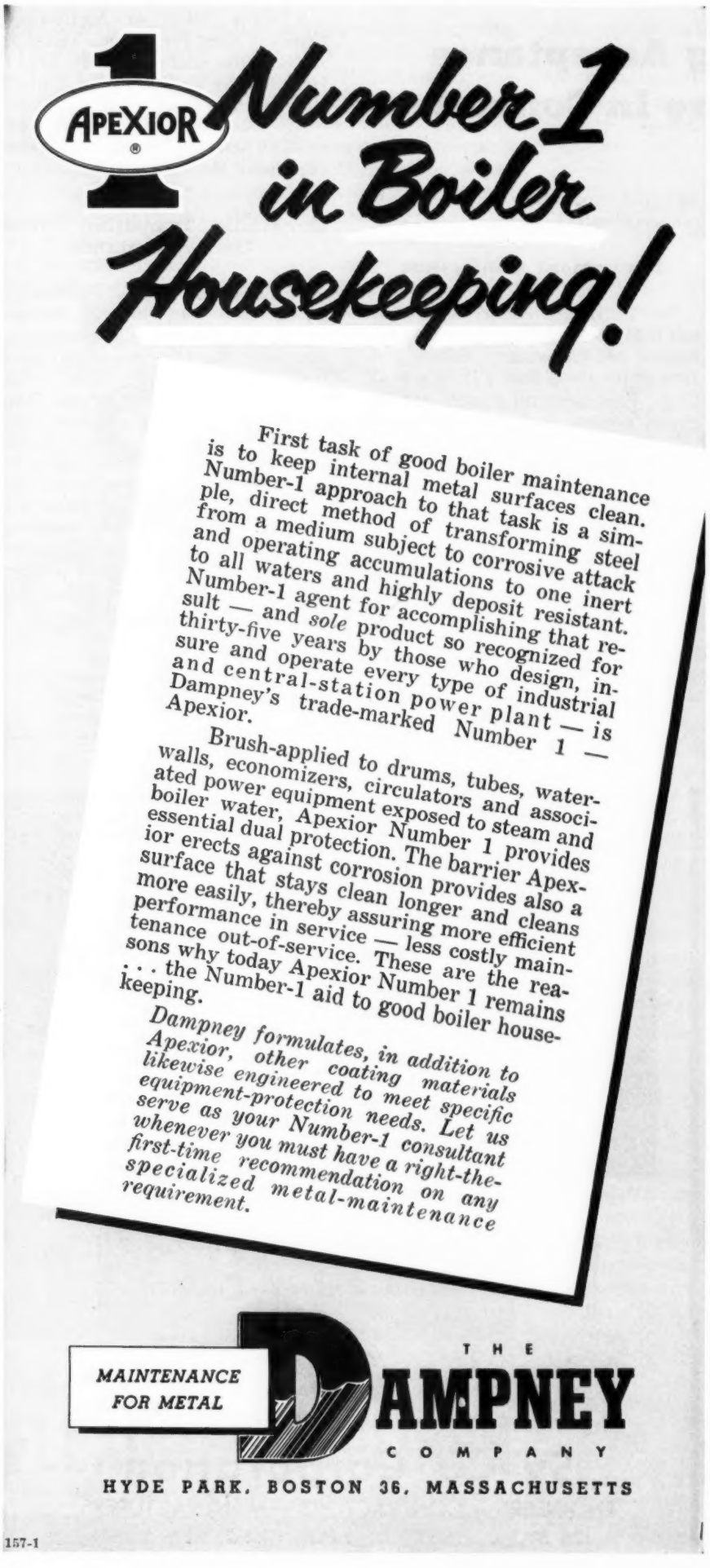
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New Catalogs and Bulletins

Any of these may be secured by writing Combustion Publishing Company, 200 Madison Avenue, New York 16, N. Y.

Synchronous Motor Control

Synchronous motors, their operation and control, are described in a two-color 16-page bulletin announced as available from the General Electric Co. Designated as GEA-5873, the publication explains the electrical operation of synchronous motors and the areas where control is essential. Problems common to synchronous motor applications and their solution by using the correct control equipment are explained in a question-answer technique.

Deslaggers

Bulletin 1016 issued by the Copes-Vulcan Division of Continental Foundry & Machine Co. shows how dual-motor drive and high striking power are combined to stop water wall buildup with wall deslaggers. Sketches and cutaway show the easy accessibility for inspection and maintenance.

Demineralizing

A 29-page booklet on water treatment by demineralizing has been prepared by the Cochrane Corp. It explains the principles of ion exchange and discusses many anion and cation exchange materials. There are curves which enable the preparation of estimates of operating costs of demineralizing systems. Operating results and flow diagrams of several existing plants are also shown in Bulletin 5800.

Single-Stage Turbine

A six-page Bulletin, No. 4206, containing design features, dimensions and performance data on the De Laval HCB single-stage turbine has been issued by the De Laval Steam Turbine Co. There is a two-page cutaway diagram of the turbine with a descriptive list of 18 design features. Dimensions of principal parts, performance data and construction materials are given.

Materials Handling

Sauerman Bros., Inc., has released a four-page brochure on long-range materials handling machines. Line drawings are utilized to provide a simple explanation of how the drag scraper, slackline cableway and tautline cableway operate. Typical installation photographs are also shown.

Electrostatic Precipitators

Operators contemplating the installation of equipment for recovering dusts, fumes, mists or other similar suspensions in stack or process gases will find much valuable data in a 40-page booklet issued by Western Precipitation Corp. The booklet summarizes the latest advancements in Cottrell precipitator equipment, outlines various types of electrode designs and gives helpful information on combination mechanical-electrical recovery systems.

Signal Transmitter

Bulletin No. 2653 published by Hagan Corp. illustrates and describes a combination 1500-psi liquid line-flow measuring element and pneumatic flow-signal transmitter equipped with square root extraction cam for linear indication, recording or control of furnace fuel and process liquids. Mention is made of the simplicity of checking the instrument by dead-weight calibration.

Pipe Insulation

Aluminum-jacketed Foamglass pipe insulation is the subject of a bulletin prepared by the Pittsburgh Corning Corp. It points out the advantages of the factory-wrapped cellular glass insulation. In addition to describing the economies made possible by the aluminum jacket, illustrated condensed specifications for the insulation of both hot and cold lines are presented.

Feedwater Heaters

Bulletin S-217 is a six-page, two-color folder which illustrates and describes latest developments in feedwater heating by the Stickle Steam Specialties Company. Features and construction of a baffle-spray type deaerating heater are included.

Thermocouples

A 42-page data book and catalog, Bulletin TC-10, has been published by the Wheelco Instruments division of the Barber-Colman Company to illustrate their complete line of thermocouples, radiation detectors and resistance bulbs. Instructions are provided for making thermocouples, and there are a number of tables showing thermocouple calibration data.

Centrifugal Pumps

Bulletin No. 237-C has been prepared by the Pennsylvania Pump and Compressor Company to describe Thrustfre 2, 3 and 4-stage pumps for heads up to 650 psig and with capacities ranging from 50 to 850 gpm. General specifications, cutaway drawings and photographs of pump details make up the remainder of the eight-page bulletin.

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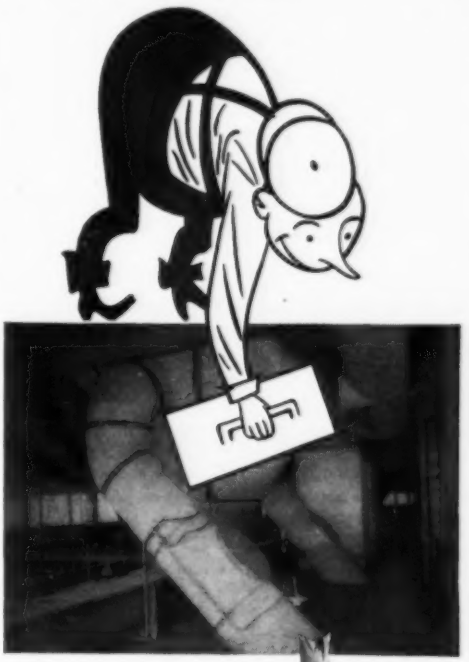

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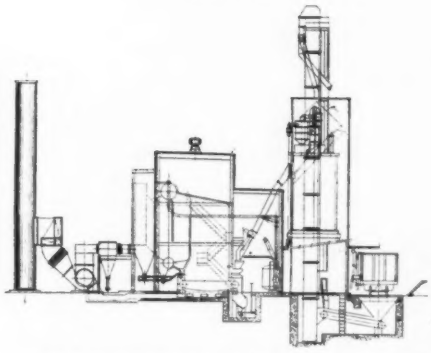

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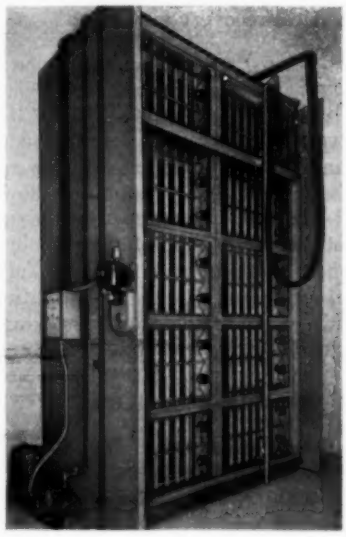


on the electronic collector-plate surfaces of the unit is flushed away by hot water from needle-spray nozzles attached to a motorized header. Typical installations are found in industrial plants, office buildings, food processing plants and hospitals.

Miniature Venturi Tube

Measurement of fluids, gaseous or liquid, in quantities considered too small for normal size Venturi or orifice can now be accomplished with the Type TF Venturi recently developed by the Simplex Valve and Meter Co., 68th and Upland Sts., Philadelphia 42, Pa. This tube comes in the following inlet sizes, $\frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{4}$, $1\frac{1}{2}$ and 2 in., with four different ratios of throat to main in each size. It may be made of cast iron, stainless steel or bronze to fit the fluid handled.

Ordinarily the Type TF Venturi is installed directly in the pipe line and requires no supplemental approach or downstream pipe section. Where the pipe line is different than the selected standard ratio Venturi, special attention must be given to the conditions of approach.

Generator Relay

When the damaging effect of negative sequence current from a faulted line approaches a pre-set maximum, Type COQ, a negative sequence overcurrent relay manufactured by Westinghouse

Electric Corp., 401 Liberty Ave, Box 2278, Pittsburgh 30, Pa., initiates the necessary action to remove the generator from the line. A current filter with output proportional to the negative-sequence input operates a Type CO overcurrent relay to initiate tripping of a circuit breaker. Rated at 3 to 5 amp, 60 cycles, the COQ has taps at 3, 3.25, 3.5, 3.8, 4.2, 4.6 and 5.0 amp. Relay characteristics are matched to generator characteristics by means of eight dial settings from "4" to "11," with "4" on the dial representing "30" for a generator characteristic. This "30" means it takes 30 seconds to close the relay contacts. A time dial setting of "11" represents a generator characteristic of "90."

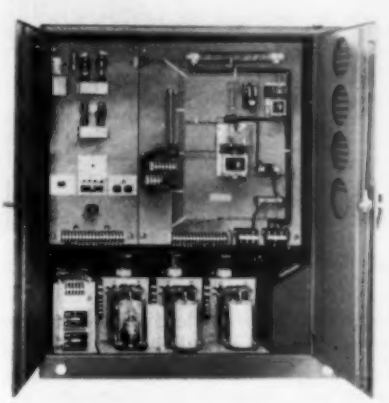
Belt Cover

A promised resistance to abrasion and tearing never before attained is the expressed belief of the Manhattan Rubber Div., of Raybestos-Manhattan, Co., Inc., Passaic, N. J., for their new conveyor belt cover, known as XDC.

This cover is an outgrowth of the manufacturer's findings that conveyor belt cover tensile strength has been overemphasized as the prime factor in belt specification. Actually most final conveyor belt failures trace back to cover wear through abrasion, cuts and tears and not cover tensional stress. The new product employs a blending of ingredients that reportedly results in a balance-of-wear between major strength members and belt cover plus a superior flex life and resiliency.

Mercury Rectifier

Adjustable speed needs on industrial applications will profit from the Xatron V*S variable voltage, power drive for mercury rectifiers, recently marketed by the Reliance Electric & Engineering Co., 1088 Ivanhoe Road, Cleveland 10, Ohio. This drive, product of four years' design research and engineering,



employs a single anode mercury pool rectifier tube, the Xatron, to convert a-c to controlled d-c variable voltage for application to adjustable-speed drive

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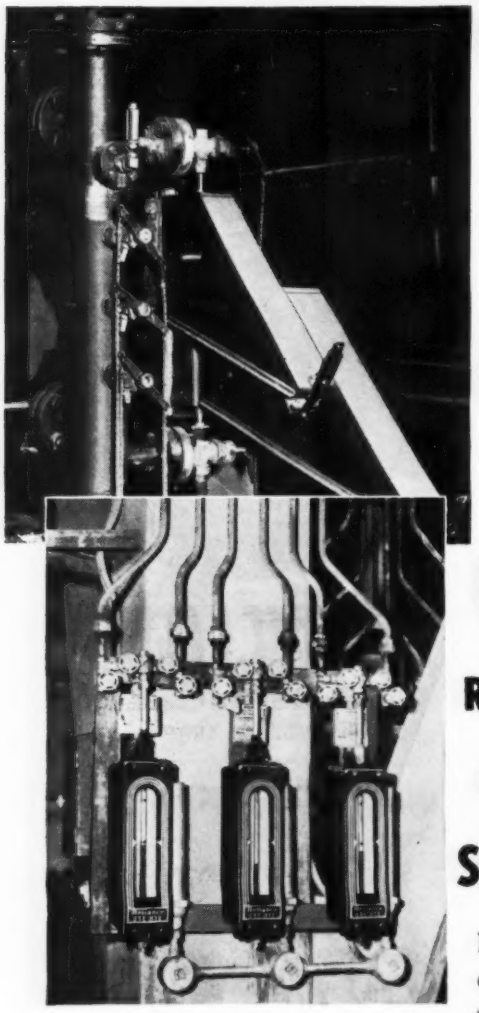

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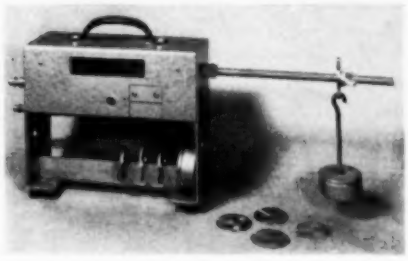

Diversey Parkway, Chicago. The device performs the same function as an air loader and may be adjusted accurately to produce any pre-determined pressure by adding or removing calibrated weights from a weighbeam. This avoids the slow process of setting output pressures with a manometer.

Weighing Scale

Where overhead clearance is limited the Transportation Div. of the Sintering Machinery Corp., Netcong, N. J., have designed an offset weighing scale for use on new or existing belt conveyors. The weight integrator scale levers and suspension framework all go under the

conveyor and the weight integrator, mounted in a dust-tight cabinet, can be located on either side of the conveyor. All transportometers include a standard, completely mechanical, gear differential integrator to automatically and continuously record the product of belt speed and momentary weight passing over the scale suspension. Capacities are governed only by conveyor belt capacity now in service.

Personals

Lance H. Cooper, chairman of the Mend Nickel Co., Ltd., has been elected to vice president of its parent company, the International Nickel Co. of Canada, Ltd., and assumed his new post January 1, 1954.

James M. Sturman was recently raised to sales manager of the newly formed Escher Wyss Division, of Cleaver-Brooks Co. from his post as West Coast sales manager of distillation units.

C. Burton Clark, with the research department of Harbison-Walker Refractories Co. since 1937, has now been named senior mineralogist.

Reliance Electric & Engineering Co. recently announced three promotions involving (1) **John Drollinger Jr.,** manager of the Toledo office to the post of manager of the renewal parts and repair division in Cleveland; (2) **William C. Mitchell,** sales application engineer in Baltimore to the position vacated by Drollinger in Toledo; (3) **Robert O. Gee,** an application engineer in the Cleveland main office to manager of service, based in Cleveland.

Three recent graduates of the Allis-Chalmers Mfg. Co. training course for graduate engineers have moved to new assignments, **Nicholas J. Balazo** and **Willard H. Melton** to superintendents in the general machinery division's service section and **Dudley B. Smith, Jr.,** to service engineer in the midwest region.

Harold W. Sweatt, president of Minneapolis-Honeywell Regulator Co. since 1934, succeeded Mark C. Honeywell, now honorary chairman, as the chairman of the board of directors. **Paul B. Wishart,** vice president and general manager, assumed the duties of president to replace Mr. Sweatt.

Gerald T. Shannon has been selected for managing engineer of the industrial engineering department of Walter Kidde Constructors, Inc., to direct that department's expanded activities.

Harold A. Anderson, vice president and eastern district manager since 1946, will join the Austin Co.'s headquarters staff at Cleveland as vice president and assistant general manager to help in planning and coordinating the general functions of the firm.

E. M. Logan and **J. L. Rainier** have been appointed service engineers for the Simplex Valve and Meter Co. with Logan working out of Florida and Rainier out of Oklahoma.

George H. Clifford, president since 1929 of Stone & Webster Service Corp., was named chairman of the board and **R. N. Benjamin,** vice president since 1948, was elected president of the business advisory service company.

Paul D. Brooks, since 1950 manager of the sales and marketing department of Ebasco Services, Inc., has been elected to the post of commercial vice president of American Gas and Electric Service Corp.

Henry A. Leilich has been appointed a project engineer for the Machinery Division of Dravo Corp. to specialize primarily in power plant engineering and construction. Mr. Leilich was formerly a staff engineer with P. F. Loftus Corp.

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have these
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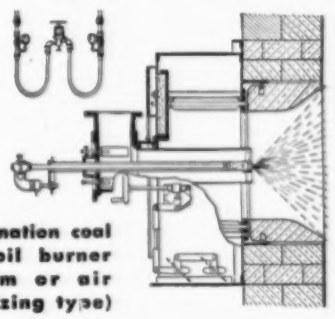
in pulverized coal
fired boilers . . .

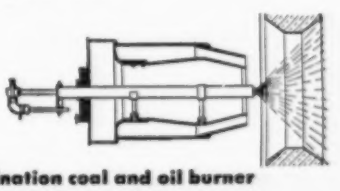
They may be installed in practically all types of pulverized coal burners, with these seven important advantages:

- They warm up cold furnaces
- They ignite pulverized coal—safely
- They assure continuous operation in case coal system fails
- They provide efficient and safe operation on bank and at low loads
- They respond almost instantly to sudden load changes
- They permit operation with oil or coal—whichever is available and lowest in cost per BTU.
- All capacities of steam, air or mechanical-atomizing types are interchangeable

The foregoing are only a few of the reasons why Enco oil-burners have been bought by a long list of leading industrial firms. Details of how Enco oil-burners can be adapted to your present pulverized coal burners will be gladly supplied—without obligation. Write The Engineer Company. 75 West St., New York, N. Y.



Combination coal and oil burner (Steam or air atomizing type)



Combination coal and oil burner (Mechanical atomizing type)

Enco Burners

Business Notes

A new alloy fabricating plant constitutes one of the highlights of **Benjamin F. Shaw Co.'s** sixtieth anniversary. This new facility has been added for processing the increasing volume and varieties of alloy steel piping ranging from ferritic low-chrome types to the austenitic chrome nickel classes and will raise the company's output for this piping for refineries, chemical plants, and power stations by 50 per cent.

Burrell Corp., Pittsburgh, Pa., has been appointed exclusive distributor in the United States for Stanton Instruments, Ltd., London, England, and their precision balances, used principally in laboratory weighings where speed and accuracy are needed.

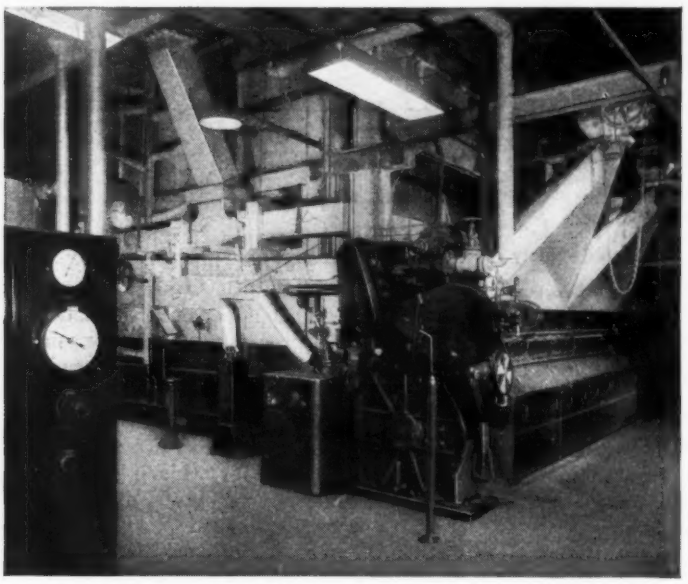
A full-size **General Electric Co.** mechanical drive turbine, Type DP, will be featured as an exhibit at a number of industrial shows and expositions during the coming year, starting with the Plant Maintenance Conference in Chicago, January 25–28. An a-c motor drives the turbine for display purposes and as the speed is varied the action of the governing valve can be observed.

Electric power supply throughout Michigan's Thumb Area was increased by 150,000 kw, November 29, when another steam turbine generator, the second of four, was put on the line at **Detroit Edison Co.'s** still unfinished St. Clair power plant. The two final units are slated for operation by July 1954.

Fairfield Engineering Co. recently announced the appointment of the Hank Thurstin Co., Denver, Colo., as their representative in that area.

Sanderson & Porter have been engaged as consultants to the aviation gas turbine division of Westinghouse Electric Corp. on the development and production of jet engines.

NATIONAL CASH REGISTER SAVES $70,000 A YEAR WITH MODERN COAL EQUIPMENT!



One of the two new boilers used to supply base steam loads for NCR's plant. Older pulverized coal boilers handle swings.

NCR recently installed two modern, stoker-fired boilers in their Dayton, Ohio plant. They supply the major part of the steam used in generating power for 28 factory buildings and heat for nearly 72 acres of floor space. The savings made have convinced NCR that for high efficiency and low costs, you can't beat an up-to-date bituminous coal-fired installation.

Big Loads! Loads run up to 300,000 lbs. per hour. Annual coal consumption is about 60,000 tons.

No smoking allowed! Located near a residential area with strict control regulations, National uses dust collectors and smoke recorders to make coal clean and convenient.

Additional case histories, showing how other types of plants have modernized and saved money with coal, are available upon request.

Before you build a new plant or remodel your present one, let a consulting engineer show you how a modern bituminous coal installation—tailored to your needs—can save you money.

With modern coal-burning equipment, you can save from 10% to 40% on steam costs. Automatic coal- and ash-handling systems can cut your labor costs to a minimum.

You're set for the future, too, with coal. Coal reserves are virtually inexhaustible. America's highly mechanized coal industry is the world's most efficient. Thus you are assured of a dependable supply of coal, at relatively stable prices, for years to come.

BITUMINOUS COAL INSTITUTE
A Department of National Coal Association
Southern Building, Washington 5, D. C.

If you operate a steam plant, you can't afford to ignore these facts!

BITUMINOUS COAL in most places is today's lowest-cost fuel, and coal reserves in America are adequate for *hundreds of years to come.*

COAL production in the U.S.A. is highly mechanized and by far the most efficient in the world.

COAL prices will therefore remain the most stable of all fuels.

COAL is the safest fuel to store and use.

COAL is the fuel that industry counts on more and more—for with modern combustion and handling equipment, the inherent advantages of well-prepared coal net even bigger savings.

FOR HIGH EFFICIENCY FOR LOW COST

YOU CAN COUNT ON COAL!